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THE DUAL NOZZLE CROSS FLOW TURBINE PERFORMANCE

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ABSTRACT

A Cross flow turbine is the most popular micro power plants because of the simple construction, reliable, but until to now, the turbine performance is still low compared with other water turbines. The purpose of this study was to examine the increase of the cross flow turbine with a dual nozzle as a hydro power generation performance. The research method is by testing and analyzing the dual nozzle Cross flow turbine performance. The Cross flow turbine best performance obtained in this study is that the best efficiency and optimal cross flow turbine with a dual nozzle of 78.80%. While the efficiency for a single nozzle cross flow turbine mounted horizontally is a little bit lower which is about 70.78%. While for the single nozzle cross flow turbine with a vertical position has the lowest efficiency of 61.92%.

Keywords: performance, cross-flow turbine, dual nozzle.

1. INTRODUCTION

Technological developments, population growth and the community economic improvement, causing a very high-energy consumption, and requires a quick and accurate strategy. Energy is one of the absolute requirements that must be fulfilled in human life [1, 2]. Electrical energy requirements increase rapidly so that an energy conversion technology is needed and of course optimize the non-fossil energy in nature utilization [3, 4, 5]. Fossil fuels are .not renewable energy sources, fossil fuel are expensive and the price fluctuating, and would increase carbon dioxide level in the atmosphere. Carbon dioxide and other substances are called as greenhouse gases because incoming solar energy into Earth's atmosphere were held to radiate back into the space so that energy is trapped and causing a global warming [6, 7]. It is very urgent now to optimize the use of renewable energy sources such as water energy. Water energy is the energy of the water displacement movement due to the influence of the earth's gravity, water moves from a high level area to low level areas, could be used as a hydroelectric power station [8, 9, 10]. Micro-hydro scale hydro energy is very attractive due to the pledge of abundant energy source, clean, inexpensive, stable, sustainable and renewable [11, 12]. Micro-scale hydro energy is widely available in rural areas as well as their future development is prospective enough to be converted into electrical energy, to meet the energy needs for local, national and international.

2. LITERATURE REVIEW

One of the effort to utilize water as renewable energy is to build a micro-hydro power plants with water, turbine and generator transmission installation as the main component, to convert the water potential energy into mechanical energy as water turbine prime mover [13]. The water energy capacity amount that can be converted into mechanical energy in the water turbine is depending on the water head and discharge [14, 15, 16].The head generate pressure on the penstock end and the nozzle could drive the turbine runner blades to turn an electrical generator. Water flow rate is the water volume mass that passing through the turbine per unit time.

A water turbine is a device that could convert water energy, which is the water pressure energy into a mechanical energy in the turbine which is used to drive an electric generator or other equipment [17]. The cross flow water turbine is widely used as a micro hydro power plant driver [18]. The excellence of a micro-hydro is firstly a simple technology, economical and environmentally friendly [19]. Secondly, the load change is slow just day to day rather than in minutes or seconds. Thirdly, the building process is fast and has a long life system, a low operational and maintenance cost. Fourthly, energy to run this system is free, sustainable, does not use fossil fuels and self-sufficiency energy [20]. Finally, has a short transmission network since the energy sources is adjacent to the consumers. A Cross Flow turbine is an impulse turbine that has a capability to convert the water potential energy, water pressure energy and water kinetic energy into mechanical energy in the form of a turbine shaft rotation [21]. The energy conversion and energy transfer occurs on the turbine blade runner. On a cross flow turbine blade, water is transferring work or power twice to the turbine runner, but most of the power is absorbed in the first level blade and at the second level blade runners. The turbine blades are mounted on a disc that is supported by the drive shaft, where this drive shaft is functioned to drive an electric generator or other equipment. Cross flow turbine as an impulse turbine absorbs energy from the water high velocity through the turbine nozzle [22].

The turbine nozzle is functioning to convert the potential energy, water pressure energy into a kinetic energy, regulate, increase the water speed and directing water jet entering the turbine blades effectively and change the water potential energy into water kinetic energy to drive the turbine blade runner [23]. Runner is one of the turbine unit components which converts the water kinetic energy interacting the runner blades causes the turbine shaft to rotate and drive a generator or other machines [24].

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Based on the above studies, the research will be done to correct the micro-hydro deficiencies that still exist, namely the still low cross flow turbine efficiency, because there are many cross flow turbine runner blades that are not optimal and get a uniform pressure water jet from the nozzle. To improve the cross flow turbine performance on this further research is by installing a dual nozzle on the cross flow turbine inlet side.

3. RESEARCH METHOD

3.1. Installation instrument

The research installation main components for a dual nozzle cross flow turbine performance are the framework installation, water pumps, water tanks, plumbing, valve, water tank and turbine holder, the dual nozzle cross flow turbine, blade, runner turbine and shaft. The turbine is made from a flat transparent acrylic fiber. The parameters measured in testing are the water flow rate, head, turbine load and rotation. The instrument installation used are the spring balance with a load regulator, Tachometer, barometer, thermometer, flow-meter to measure the water flow rate entering the turbine and water level indicator pipe. A pulley is mounted on the turbine shaft to operate the variable loader to measure the turbine torque. Turbine blades mounted on turbine runner wheel. The test data were analyzed using equation (1), (2) and (3) to get the cross flow turbine performance, turbine efficiency of the dual nozzle cross flow turbine. The test installation diagram could be seen Figures 1 and 2 as follows:

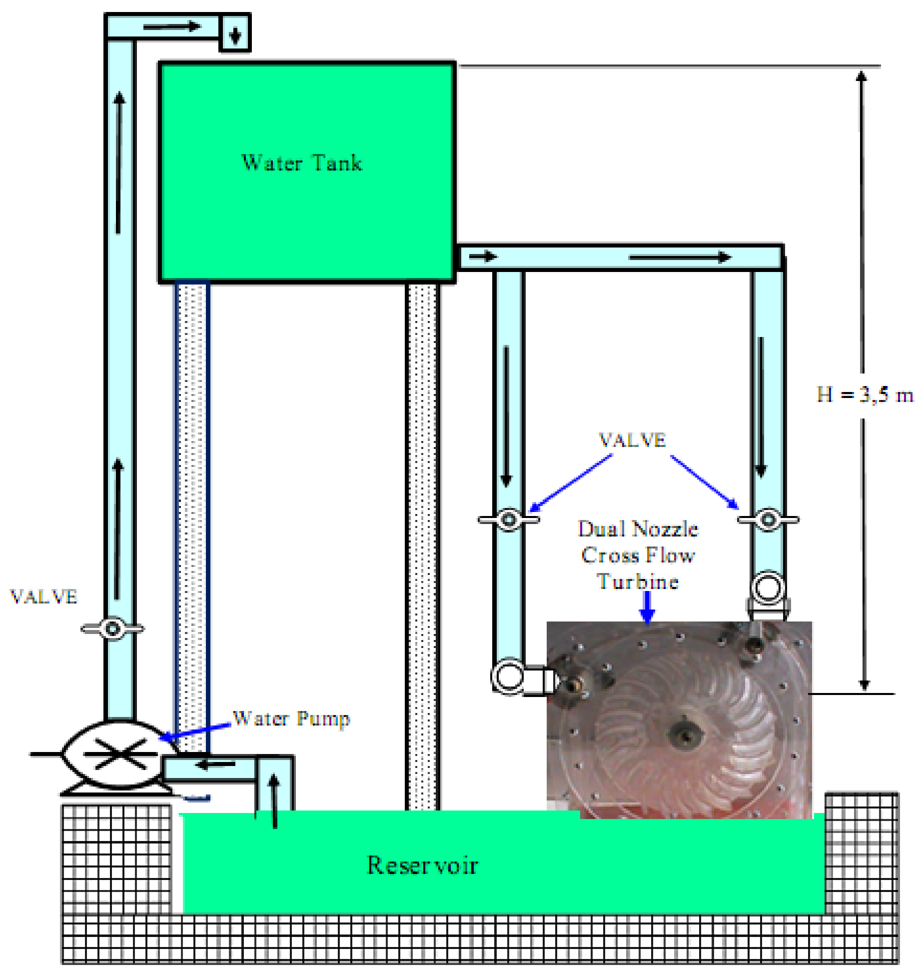

Figure-1. Test Installation diagram.

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(a) Dual Nozzle Cross Flow Turbine (b).Dual Nozzle Cross Flow Turbine Installation

Figure-2. Component and installation unit dual nozzle cross flow turbine [1].

Table-1. Specification turbine.

Turbine type	Dual nozzle cross flow
Manufacture	Made of Indonesia (2012)
Outer Runner Diameter	200 mm
Inner Runner Diameter	110 mm
Runner width	40 mm
Blades number	24 pieces
Turbine Material	Fiber Glass
Shaft length	300 mm
Shaft diameter (D_s)	12 mm
Nozzle	Dual
Nozzle Diameter	12 mm
Pulley Diameter	54 mm
Turbine Capacity	0,01 – 100Watt
Rotation of Turbine	$\leq$ 1000 rpm

3.2 Data collection methods

a) Preparing the cross flow instruments, tools and installation

b) Fill the tank with water and make sure the water tank have a head as needed for the experiment

c) Prepare for the unit flow circulation, water level head and water flow should be controlled by setting the opening valve based on testing needs.

d) Perform testing, reading, data collection and check the data collection accuracy

e) Analysis and conclusions

3.3 Dataanalysis

The water power turbine on the water inlet proportional to the pressure head and water discharge magnitude [1,3] and could be calculated by the equation:

Water Power:

$$P_{water} = \rho \; g \; Q \; H (Watt) \quad (1)$$

ρ = water density (kg/m^3)
g = gravity (m/s^2)
$H_N = H_{gross} - H_{loses}$ (m)
Q = water flow rate flow rate (liter/s or m^3/s)

Turbine power:

$$P_{turbin} = \tau . \varpi \quad (Watt) \quad (2)$$

τ = Turbine Torque (Joule)
ϖ = angular velocity (rpm)
n = Turbine rotation (radian / s)

The turbine efficiency can be calculated by the following equation:

$$\eta = \frac{P_{turbin}}{P_{water}} \; x \; 100\% \quad (3)$$

4. RESULTS AND DISCUSSIONS

Results of The Cross Flow Turbine with a Dual nozzle performance testing result is done by varying the water flow rate gets into the turbine blades on a load and constant head. Based on the dual nozzle cross flow turbine testing result that uses a larger Dual nozzle it is found that the turbine power generated due to the water jet from the nozzle is more effective to drive the turbine runner blades because it is receiving a bigger energy from the water jets. However, the operation of a single nozzle cross flow turbine fitted with a horizontal position nozzle began to decline and the single nozzle cross flow turbine with a vertical position nozzle has the lowest power generated.

On Figure-3 it is seen a graph about the water flow rate variation and cross flow turbine power relation for a cross flow turbine uses a dual nozzle, a single horizontal nozzle and single vertical nozzle. From the graph it is clearly seen that the bigger the turbine inlet flow rates the bigger the power would be increased. The increase in turbine power is due to the larger water flow

VOL. 11, NO. 13, JULY 2016 ISSN 1819-6608
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rate, water mass and kinetic energy getting into the turbine inlet. Figure-3 also shows that the cross flow turbine using a Dual nozzle which is equal to the highest power $P_{turbine}$ = 6.03 Watt. The best power and optimal, could be achieved because of the water discharge entering the turbine runner blades and could produce a purposeful water spray from the nozzle, more uniform and finally more turbine blades are to be shot by the Dual nozzle water jet.

For the turbine experiment that is using a single horizontal, the water jet from the nozzle began somewhat reduced so that blade driven would be also reduced and, of course, the energy absorption from the water jet nozzle would be decline too, resulting a lower turbine power produced, with a result of $P_{turbine}$ = 5.34 Watt. For the cross flow turbine with a single vertical nozzle smaller turbine power is generated. It is because just few turbine blades are hit by the water jet. The water jet from the nozzle and water energy absorbed by the turbine, compared with the single horizontal nozzle, is smaller, so that the turbine rotation and turbine power is lower, the maximum power generated $P_{turbine}$ = 4.67 Watt.

A cross flow turbine that uses the a dual nozzle was a very influential result to increase the turbine power compared with a cross flow turbine using a single nozzle mounted horizontally or mounted vertically, all of these kind of turbine power increased along with increase of the water flow rate entering the turbine, but the turbine power tends to decline when the water flow rate reaches maximum.

From this study it is found that the cross flow turbine performance improvement is strongly influenced by the nozzle number and the nozzle position. A cross flow turbine with a dual nozzle produces the largest power because the turbine blade runner is capable to change a bigger potential energy and kinetic energy from the water jet into the turbine shaft mechanical energy. While for the horizontal and vertical single nozzle turbine starts to decline and reaches the lowest efficiency.

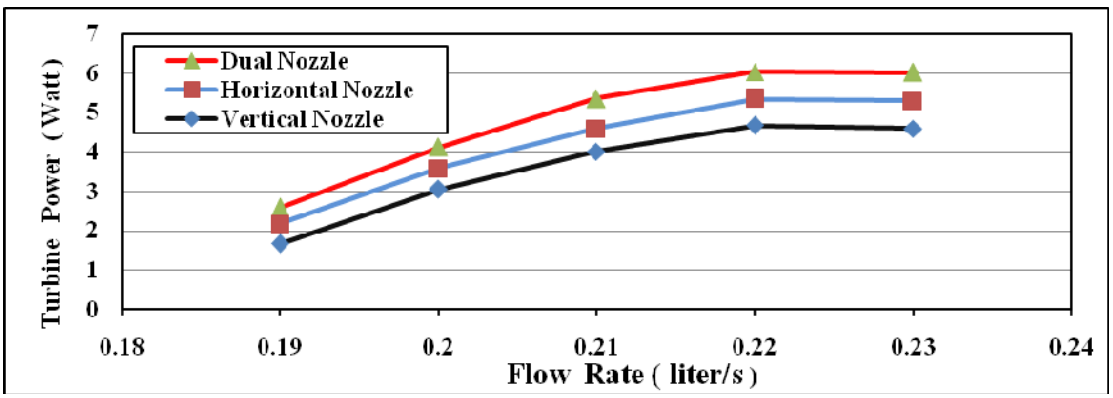

Figure-3. Turbine power vs. water flow rate.

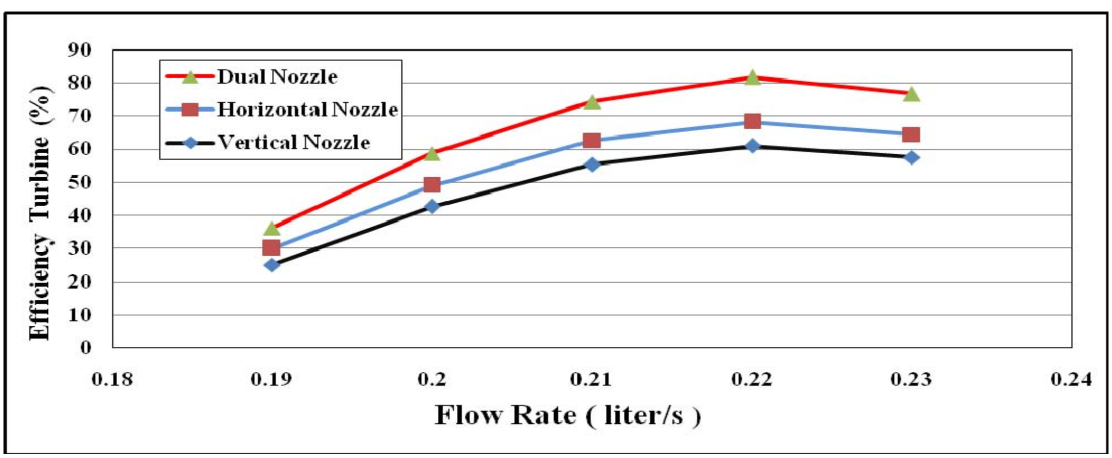

Figure-4. Efficiency turbine vs. water flow rate.

On Figure-4 it is shown that every water flow rate getting into the turbine runner variation would change the turbine efficiency result. Also the nozzle position would also give a certain turbine efficiency result. The cross flow turbine with a single vertical nozzle position has the lowest efficiency $\eta_{turbine}$ = 61.92%, since the capability of

VOL. 11, NO. 13, JULY 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

converting the water power into a turbine power is still lacking. The turbine that uses a horizontal single nozzle increased by $\eta_{Turbine}$ = 70.78%% because the water power is also growing as the turbine shaft driver. Furthermore, the cross flow turbine with a dual nozzle obtained the highest efficiency $\eta_{Turbine}$ = 78.80%. The cross flow turbine that uses dual nozzle efficiency increased significantly. This is due to the water flow rate getting into the turbine increased would resulted a larger water jet with a good and effective hit to the turbine blades and would resulted the highest efficiency. Most of the water energy can be changed to mechanical energy in the turbine shaft.

The use of a dual nozzle in a cross flow turbine result a good turbine performance. The dual nozzle is very good as an energy conversion from water pressure into kinetic energy. The water flow rate regulating is easy, the water directors and water jet entering the turbine blades could improve the cross flow turbine power performance optimally. The turbine efficiency reaches the optimum value at the time where the water flow rate nearly reaching the maximum point, and would then lowered down when the water flow rate reached the maximum point as depicted in Figure 2. The efficiency decreased is caused by the water flow entering the turbine increases and produces a chaotic situation and even causing a lot water jet reflection, undirected, leak and flow outside the turbine blade and could reduce the turbine power.

5. CONCLUSIONS

A dual nozzle cross flow turbine performance would have a better performance compared with the conventional cross flow turbine. It is because of the water jet power hitting the turbine blade is more evenly and well guided. The water energy from the nozzle is effective and pushing more turbine blades compared with the horizontal single nozzle cross flow turbine or the vertical single nozzle cross flow turbine. The most optimal efficiency was generated by the cross flow turbine with a dual nozzle, which is 78.80%, while the cross flow turbine with a single horizontal nozzle efficiency reached an efficiency of 70.78.%. For the cross flow turbine with a single vertical nozzle efficiency reached the lowest efficiency of 61.92 %.

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