DUAL NOZZLE CROSS FLOW TURBINE AS AN ELECTRICAL POWER GENERATION

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ABSTRACT

Rapid technological advances require electrical energy for its operations and human needs fulfillment. Water energy is abundant in nature and could be used as an electrical energy source. The cross flow is most widely applied as micro-hydro power plants because it can operate at low head, a small water discharge, simple in construction, easy and inexpensive maintenance. But the cross flow performance is still low, since it is only uses one turbine nozzle, so that the turbine blade effectiveness in absorbing water energy is still low. This aim of this study is to test the cross flow turbine performance with a dual nozzle as electricity generation. The results showed that the Cross Flow turbine performance with dual nozzle produces a larger power output and higher efficiency even increase significantly the electric power output as big as 4,038 Watt, with a system efficiency of 52.72%. While the cross flow turbine with a single horizontal nozzle has a lower performance which is 3,468 Watt, with system efficiency of 45.97% and on a single vertical nozzle which is 2,925 Watt with a system efficiency of 38.78%.

Keywords: dual nozzle crosses flow, electrical power generation.

1. INTRODUCTION

Energy requirements for human life today is very high, hydro energy on micro-hydro scale is very attractive to be used as a source of clean energy, sustainable, widely available in the countryside, renewable and prospects its development [1, 2]. Electrical energy is a vital energy and infrastructure is required in households, public and industrial. Excellent water turbines to convert water energy into mechanical energy, is by driving electrical generators [3].

Electrical energy generation based from fuel oil, gas and coal should be reduced because fuel reserves dwindling fossil fuels, causing air pollution, the greenhouse effect and rising the temperature [4]. In connection with this situation, it is very urgent to developed and exploited water energy to the maximum as a renewable energy source, clean and environmentally friendly energy which is driving the water turbine power plant [5].

2. LITERATURE REVIEW

In rural and remote areas in micro-hydro power plants that use a lot of cross-flow turbines are urgently needed [6]. Micro-hydro power plant consists of main components, namely the water reservoir, piping installation, water turbine, generator and electrical installation [7]. Cross Flow turbine is an impulse turbine which is able to transform the water potential energy into kinetic energy in the nozzle which emits the water jet to hit the turbine blades and resulted the wheel or turbine runner rotating [8]. The turbine nozzle is functioned to direct water jets to hit the turbine blades so that the turbine runner could spin. The cross flow turbine performance is strongly influenced by the water jet effectiveness produced by the nozzle to move the turbine blades [9].

Micro Hydro Power Generation use a lot of Cross-Flow turbine, being able to operate at a low head and under a small water flow rate, because ones the water jet from the turbine nozzle entering the turbine runner it would hit the blade twice and move the turbine blades [10, 11]. The Cross Flow turbine is an impulse turbine which has a runner with curve blades mounted on it like a cylindrical water wheel [12]. This kind of turbine has a horizontal shaft, which has a radial axial flow or transversely to the turbine blades and the water jet is entering through the turbine blade edge [13, 14]. The cross flow turbine performance could be optimal if the number of blades that get the water jet energy is bigger, equitable, balanced, and more effectively that the turbine blade could absorb the energy to be converted into mechanical energy on the turbine shaft as a driving electrical generator [15, 16, 17].

3. RESEARCH METHOD

3.1 Installation instrument

On the turbine test rig installation and the testing instrument used was a water pump, flow rate regulator valve, dual nozzle cross flow turbine, water tank, reservoir, pipes, pulley, belt, flowmeter, tachometer, generator, voltmeter, ammeter, load balancer. The research installation scheme is shown in Figure-1 and Figure-2 as follows:

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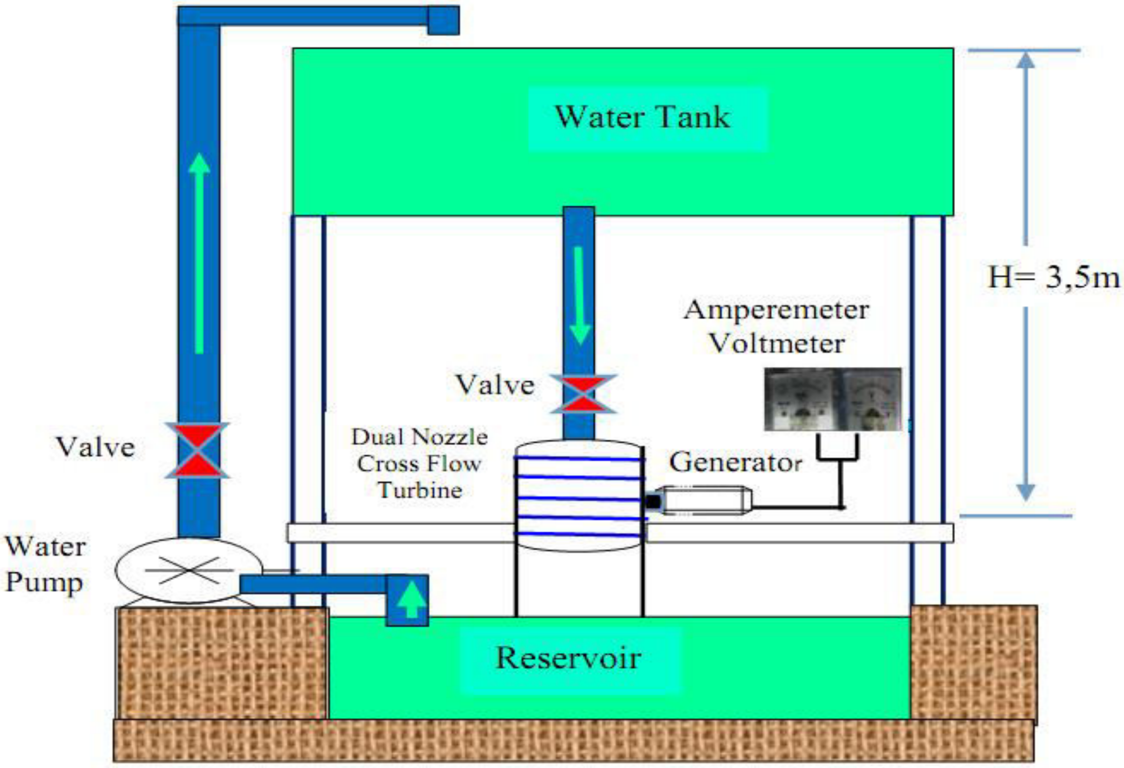

Figure-1. Test Bed installation.

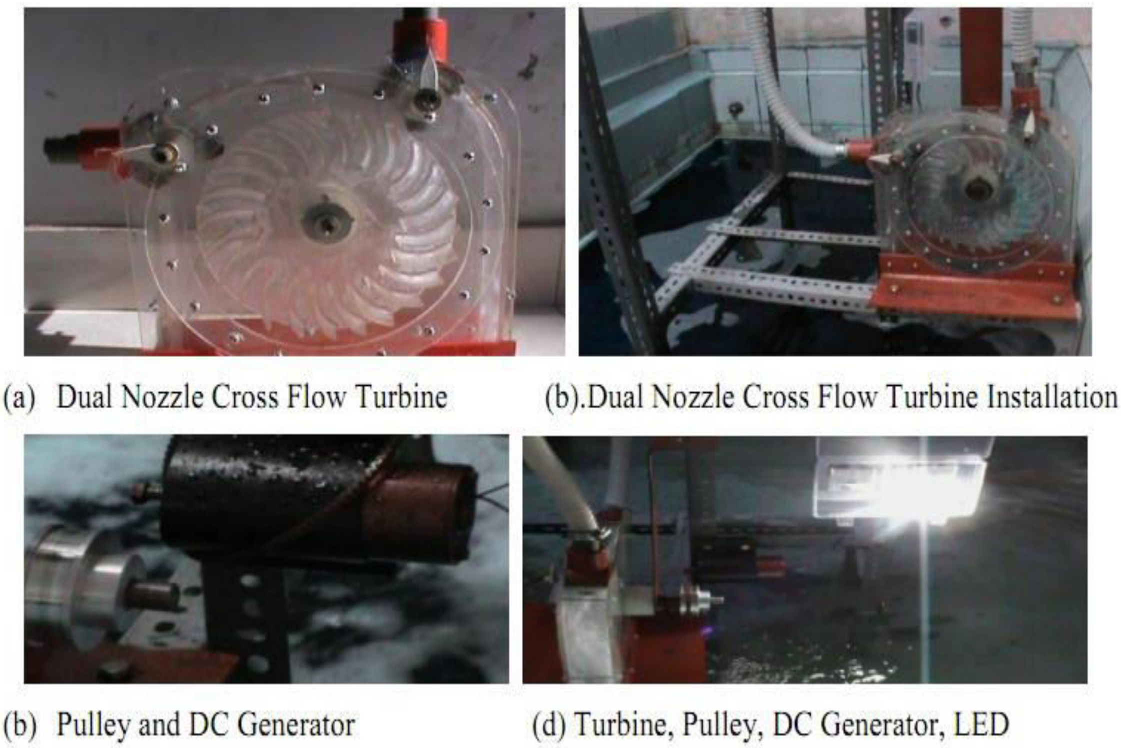

Figure-2. Dual nozzle cross flow turbine and equipment test.

Table-1. Dual nozzle cross flow specification.

Manufacturer	Indonesia (2012)
Type	Double Nozzle Cross Flow Turbine
Power capacity	0,01- 100 Watt
Blade number	24 pieces
Outer runner diameter	20 cm
Inner runner diameter	11 cm
Turbine rotation	≦ 1000 rpm
Blade, Runner and Casing material	Fiber Glass
Shaft diameter	12 mm
Pulley diameter	5,4 cm
Belt type	Plate
Nozzle diameter	12 mm

Table-2. Generator specifications.

Manufacturer	England (2005)
Type	Direct Current (DC)
Voltage	0.01- 20 Volt
Electric current	0.01- 5 Ampere
Rotation	≦1500 rpm

3.2 Testing and data collection

The test procedures and data retrieval done is as follows:

a) Prepare the installation by checking the condition of all the instruments and testing all the dual nozzle Cross Flow Turbine tools
b) Start the water pump to fill the water reservoir tank according to the head or water level needed.
c) Setting the water discharge valve drive for the turbine water flow rate,
d) The first test done is on the nozzle vertical position, horizontal and combined for the horizontal nozzle and vertical nozzle,
e) Read and record the test data from the bench observation.

3.3 Data analysis

The data were analyzed by using the following equation:

Water power:

$$P_{Water} = \rho.g.Q.H_{Net} \text{ (Watt)} \quad (1)$$

ρ = Water density
g = Acceleration due to gravity
Q = Water flow rate
H_{Net} = H_{gros} - H_{loses}

Generator power

$$P._{Gen} = V.\ I \text{ (Watt)} \quad (2)$$

V = Voltage
I = Electric current

System efficiency

$$\eta_{System} = \frac{P_{Gen}}{P_{water}} x100\% \quad (3)$$

4. RESULTS AND DISCUSSIONS

The research results through a precise testing and observation in the study is shown in Figure of chart 3, 4. The result suggested that the correlation effect with the water flow rate amount, which is the water entering the cross flow turbine is strongly influenced by the water flow amount entering the turbine runner and also the nozzle position and nozzle number used by the cross flow turbine [1, 2]. But there is a new phenomenon discovered that the water flow rate discharge of the same performance with a single vertical nozzle is lower, while using the single horizontal nozzle increases and significantly a higher improvement in the double nozzle cross flow turbine. This is happens because the cross flow turbine with a vertical nozzle the water jet is just move a little water turbine blades, while on the horizontal nozzle, more blades are push by the water jet, whereas with a duel nozzle the water jet pushes more blades. These blades are effectively absorb the water energy to converted it into a mechanical energy on the turbine shaft, so that the runner speed of rotation would be higher and of course the turbine power would be bigger to drive the electric generator and get a greater electric power production [3, 4].

The power generator, which is driven from a cross flow turbine, performance is a measure of cross flow turbine in this study, showing that the relationship between the water flow rate and the turbine nozzle number is very much affecting the turbine and generator performance. The results showed the on a constant head with a water flow rate variations, indicating that the electric power and turbine efficiency of the system is directly getting bigger with the increases of water flow rate, meaning that a greater water power entering the turbine to drive the generator [5].

Then the generator is able to get the voltage, electric current and finally the power generation increase. But when it reaches a certain maximum flow rate, a decline occurs, this due to the maximum flow rate are head loss, cavitation, water flow reflected, water collision behind the blade and flow turbulence [6, 7] and it can be stated clearly on graph 3 and graph 4 as follows:

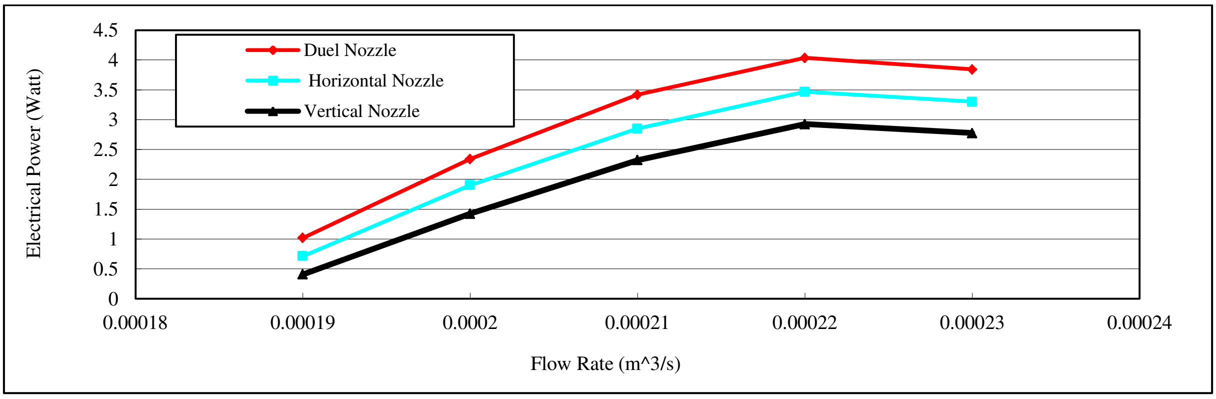

Figure-3. Electrical power vs water flow rate.

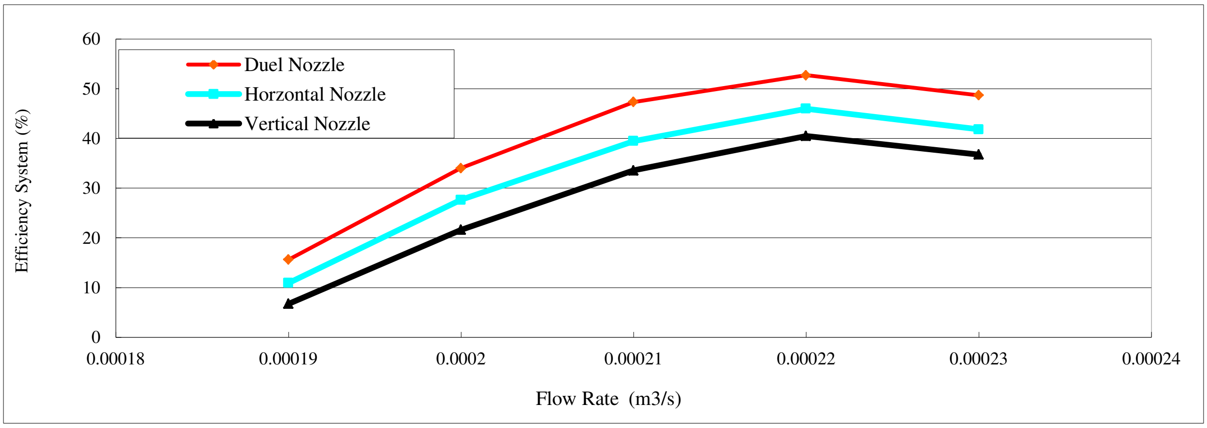

Figure-4. System efficiency vs water flow rate.

5. CONCLUSIONS

Based on the results of this study it can be concluded that the results are very satisfactory, because the cross flow turbine with dual nozzle as an electrical power generation has a better performance. The P_{gen} = 4.038 Watt, η_{sys} = 52.72%, compared with the single horizontal nozzle system with a P_{gen} = 3.468 Watt and η_{sys} = 45.97% and the single vertical nozzle system P_{gen} = 2.925 Watt, η_{sys} = 38.78%. This is due to the cross flow turbine blade with a dual nozzle turbine blade could absorb more and effectively energy from the water, compared with the cross flow turbine with a single nozzle.

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REFERENCES

[1] Marco Sinagraa, Vincenzo Sammartanoa, Costanza Aricòa, Alfonso Collurab, Tullio Tucciarellia. 2014. Cross-Flow turbine design for variable operating conditions 12th International Conference on Computing and Control for the Water Industry, CCWI2013. Elsevier. Procedia Engineering. pp. 1539-1548.

[2] Olivier Paish. 2002. Small Hydro Power: Technology and Current Status. International Journal, Renewable and Sustainable Energy Reviews, Elsevier. 6: 537-556.

[3] S.U. Patel, Prashant. N.Pakale. 2015. Study On Power Generator By Using Cross Flow Water Turbine In Micro Hydro Power Plant. International Journal of Research in Engineering and Technology eISSN: 2319-1163 | pISSN: 2321-7308.

[4] 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.

[5] Muhammad Adil Khan and Saeed Badshah. 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, 2014 ISSN: 2040-7459; e-ISSN: 2040-7467.

[6] Bernhard Pelikan. 2004. Guide on How to Develop a Small Hydropower Plant. ESHA 2004.

[7] Bilal Abdullah Nasir.2013.Design of Micro - Hydro - Electric Power Station. International Journal of Engineering and Advanced Technology (IJEAT), ISSN: 2249-8958, 2(5).

[8] Bryan, R. C. and Sharp, K. V. 2013. Impulse turbine performance characteristics and their impact on Pico-hydro installation, Renewable Energy Journal, Elsevier. 50: 959-964.

[9] J. De. Andrea dkk. 2011. Numerical Investigation of the Internal Flow in a Banki Turbine, International Journal of Rotating Machinery. 2011(Article ID. 841214): 12.

[10] Haurissa J, Soenoko R. 2010. Performance and Flow Characteristics Lattitude With Addition in Nozzle, Turbine Blades Second Level. IJAR International Journal Economics And Engineering. (4): 30-32. Azerbaijan.

[11] Kiyoshi Kokubu,Toshiaki, Kanemoto, Sung-Woo Son,Young-Do Choi. 2012. Performance Improvement of a Micro Eco Cross-Flow Hydro Turbine Journal of the Korean Society of Marine Engineering. 36(7): 902-909, ISSN: 1226-9549.

[12] Kosnik.L. 2010.The Potensial for Small Scale Hydropower Development in the US. Energy Policy (Elsevier). 38. 5512-5519.

[13] Loice Gudukeya, Ignatio Madanhire. 2013. Intern Efficiency Improvement of Pelton Wheel and Cross Flow Turbines in Micro-Hydro Power Plants: Case Study. International Journal of Engineering and Computer Science, ISSN: 2319-7242, 2(2): 416-432.

[14] N. H. Costa Pereira and J. E. Borges. 1996. Study of the nozzle flow in a Cross flow Turbine. Int. J. Mech. Sci. 38(3): 283-302.

[15] Soenoko. R, Rispiningtati, Djoko Sutikno. 2011. Protype of a Twin Kinetic Turbine Performance as a Rural Electrical Power Generation. International Journal of Basic and Applied Scientific Research, ISSN: 2090-424X, pp. 1686-1690.

[16] Tejaswini Gharge, Supriya Shintre, Shruti Bhagwat, Rasikh Solkar, Dhanashree Killedar, Mahesh Kulkarni. 2013. Design, Development of Micro Hydro Turbine and Performance Evaluation of Energy Generation for Domestic Application. International Journal for Research in Science Engineering and Technology. IJRSET ISSN: 2394-739. 2(2): 41-46.

[17] Young-DoChoi† . Sung-Woo Son. 2012. Shape Effect of Inlet Nozzle and Draft Tube on the Performance and Internal Flow of Cross-Flow Hydro Turbine. Journal of the Korean Society of Marine Engineering. 36(3): 351-357, ISSN: 2234-8352(Online) / ISSN: 2234-7925(Print)).