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IMPROVEMENT OF PERFORMANCE CROSS FLOW TURBINE WITH DUAL NOZZLE

Corvis L. Rantererung[1], Sudjito Soeparman[2], Rudy Soenoko[2] and Slamet Wahyudi[2]
[1]Department of Mechanical Engineering, Paulus Christian University of Indonesia, Makassar, Indonesia
[2]Department of Mechanical Engineering, Faculty of Engineering, Brawijaya University, Malang, Indonesia
E-Mail: corvisrante@yahoo.com

ABSTRACT

This study describes the analysis of the effect of using a dual nozzle toward the Cross flow turbine performance. The dual nozzle used is mounted on a horizontal and a vertical position, round-shaped cross-section and serves to direct water jets entering the turbine runner blades and convert the water potential energy. The purpose of this study is to test the Cross flow turbine performance increase with a dual nozzle as a hydropower generation by varying the load on the turbine shaft. The research method is by doing a test to find out the dual nozzle Cross flow turbine performance in the laboratory and finally analyze it empirically. From the test data result and from the data analysis it is found that the Cross flow turbine with a dual nozzle could have an optimal efficiency and a better performance.

Keywords: improvement cross flow turbine, dual nozzle.

1. INTRODUCTION

States that the classification of water turbine [1] comprises two groups: i). The Impuls Turbine include: Pelton turbine, Cross flow and Turgo. ii). Reaction turbine, include: Francis turbines, Kaplan and Propeller. The reaction turbines are turbines that harness the water potential energy to drive a turbine blade. The reaction turbine blade has a special profile which causes a decrease in water pressure when water passing through the turbine blade [2]. This pressure forces difference on the runner blade could rotate the turbine runner. The reaction turbine runner is completely immersed in water and is fully equipped in the turbine casing. The impulse turbines are turbines that harness the water potential energy that converted into kinetic energy in the turbine nozzle [3]. The water jets from the nozzle with very high pressure and velocity hits the turbine blades, causing the flow direction changed resulting in a change of momentum (impulse) and the rotating turbine blades [4]. The impulse turbines have the same pressure, because the pressure of the water flow out of the nozzle is equal to the surrounding atmospheric pressure. The main parts of the turbine [5] are (a). Turbine blades as the water pressure jet load recipient from the nozzle, (b). Nozzle is functioned to drive and pass the energy produced by a water jet, (c). Shaft as the mechanical energy conversion from the turbine blade, (d).Bearing as a turbine shaft support, (e). Turbine casing as the protector and integrate all components of movable and immovable turbine part [6].

The water turbine selection to be used are mostly based on the available water head [7]. In general, impulse turbines are used for high water head, while reaction turbines are used for low water heads. The water turbine utilization based on the high head usually are the Kaplan Turbine (2m <H <100 m), Francis turbine (5m <H <500 m), Pelton Turbine (H <300 m) and the Cross Flow Turbine (2 <H <200 m) [8].

The Cross flow turbine, water is entering the turbine in two stages before the water leaves the turbine runner [9]. Cross flow turbines has low efficiency compared with other water turbines. There are still many blades that has not yet hit by the water jet pressure from the nozzle Also the clearance between the turbine runner and casing is too large that there is a big power loss and a big head loss. The medium and low scale power generating with Cross flow turbines also still has a very big loss. The head loss also resulted in a loss of mechanical energy in the turbine runner blades. But this kind of turbine is very interesting; because as a small power generator in an area that has a small water potential energy, this kind turbine could be installed with a low investment and could support the rural electrification program [10]. In rural and hilly areas, especially where there is no electricity, where a potential for abundant water is very good for micro hydropower plants development for public use and can be managed by a local technician [11]. Most of the components and equipment of small scale plant can be developed locally and in a simple way. Reliable equipment for the development activities success, require a special attention to improve the cross flow turbine performance. Some points to be considered are the use of effective cost, technically standard and reliable as a portable electric generator for rural areas applications [12]. Manufacture and development utilizing local materials and products that is reliable and available on site.

Cross flow turbine attract the most attention by practitioners and micro-hydro power plants business because it can be used at a small water flow rate and low head. Besides cross flow turbine has a small size, compact construction, simple and economical. The operation and maintenance does not require high educated operator. The turbine manufacture is just uses local components, a small amount of material and low cost as well as long life time [13]. Since the cross flow turbine discovery by Michell Bangki, much research has been done in laboratory, simulated with the help of software and testing directly in the field and tests the design parameters of the turbine, such as the nozzle inward angle, the blades number, the turbine runner diameter ratio, runner width and the nozzle dimensions.

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Based on the background described above, a research will be done to optimize the Cross flow turbine power and efficiency through the existing weaknesses improvement. As mentioned above that not all blade share effective and equitable receive and absorb the turbine nozzle water spray energy. To improve the cross flow turbine performance then it is necessary for the development and testing through a research continuation with the use of a dual nozzle in a cross flow turbine. The purpose of this research is to create a simpler cross flow turbine nozzle prototype model with a dual nozzle.

The cross flow turbine is able to convert the water energy in the form of potential energy, pressure energy, kinetic energy into a mechanical energy to rotate the turbine shaft [14]. The turbine blade is a component that serves as an absorbent and water energy conversion into mechanical energy to drive the turbine. On a cross flow turbine, the turbine is water is working on the runners twice, namely when water enters the first runner stage and then the water crossing to push the runner on the second blade level before leaving the turbine runner. Energy passing through the first turbine level is absorbing the highest water energy compared with the energy absorbed by the second level [15]. Turbine disc is the turbine blade holder as well as the support of the turbine shaft driving a generator or other equipment. Cross flow turbine as an impulse turbine receive and absorb the kinetic energy of high-speed water through a turbine nozzle [16].

On the numerical study by selecting the nozzle shape and nozzle width on the smallest blade space would also improve the Cross flow turbine performance [17]. On the maximum nozzle width choice the water jet speed coming out from the first stage would be bigger than the water speed coming in the stage blade runner. On the first stage water exit velocity has the same magnitude and has a same direction go in into the second stage and the relative speed of the first stage has the same magnitude as well. Nozzle mounted on a cross flow turbine is used to direct the water jets and converts it to potential energy while the water pressure energy was then converted into kinetic energy. Another function of the nozzle is to regulate the nozzle, increase speed and form the water jet focused into the turbine blade entry effectively and altered all of the various forms of water energy such as water potential energy into water kinetic energy to produce turbine power to move the turbine runner [18].

2. LITERATURE REVIEW

2.1 Hydraulic power

The Hydraulic power is the power generated from water potential energy which was delivered from a certain height. The water power entering the turbine inlet is proportional to the pressure head and water discharge [19] can be calculated by the equation:

$$P_{water} = \rho\, g\, H_n . Q \qquad (1)$$

where

ρ = water density
g = gravitational constant
Q = water volumetric flow rate
H_n = net head= $H - h_f$

$$h_f = f\,\frac{L\,V^2}{D.2.g} \qquad (2)$$

Where

f = Darcy friction factor
L = pipe length
V = water jet velocity
D = pipe diameter

2.2.Turbine power

Turbine power is the power generated by the turbine by converting the water energy into mechanical energy in the form of turbine shaft rotation. Turbine power can be denoted by the symbol $P_{turbine}$ and the amount of power a turbine [20] is calculated by the following equation:

$$P_{turbine} = \tau\,.\omega = \tau.\,\frac{2.n}{60} \qquad (3)$$

Where

T = Turbine Shaft torque
ω = Angular speed
= 2π n/60
n = Turbine rotation

The turbine speed was measured directly using a tachometer. Simply to get the turbine torch is by multiplying the force arm with the arm radius. The greater the force arm the greater the torque be produced and would cause the turbine rotates. The turbine torque was measured using a spring loaded on the breaking system [21], and can be calculated by the following equation:

$$\tau = F.\, r \qquad (4)$$

where

F = the break force given to the turbine shaft
r = pulley radius

2.3.Turbine efficiency

The turbine efficiency is a ratio between the turbine power output to the turbine power input or the turbine power toward the water power. The turbine efficiency [22] can be calculated by the following equation:

$$\eta = \frac{P_{turbine}}{P_{water}}\, x\, 100\% \qquad (5)$$

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3. RESEARCH METHOD

The testing activity in this study was using some equipment as follows:

a) A Cross Flow Turbine with dual nozzle that consists of blades, runner, shaft, bearing, nozzle and a turbine casing as a room to install the turbine and nozzle and steer the water jets.
b) The nozzle is a turbine component that functioned to organize and direct the incoming water jet.
c) Water tank to store water in a certain height.
d) Water pump is used to pump water from the reservoir in to the water reservoir tank.
e) Pipes as a channel to drain the water from the reservoir to the water tank and from the water tank to the turbine
f) Valve is functioning as a water discharge capacity regulator.
g) Reservoir is a source of water to be pumped to the water tank.
h) Flow meter for measuring the water flow rate entering the turbine.
i) Meter to measure the height of water fall (head) of the tank entrance to the turbine.
j) Spring Balance to organize and measure the turbine break load.
k) Tachometer for measuring the turbine rotation

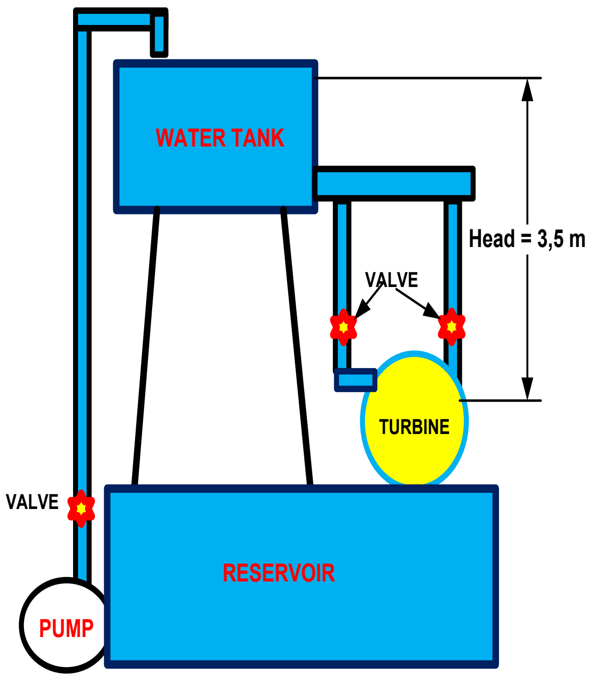

Figure-1. Schematic of testing instaltion.

The data collection and analysis is conducted in a research sequence stages as follows:

a) Preparing the dual nozzle Cross flow tubine 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

4. RESULT AND DISCUSSIONS

The cross flow turbine with a dual nozzle performance test result is done by varying the turbine load by setting the incoming water flow into the turbine blades on a constant head condition. The cross flow turbine with a dual nozzle has a higher power turbine result. This is because on a dual nozzle cross flow turbine the nozzle water jet could produce an evenly water flow and could effectively hit the turbine blades. Each turbine blade could receive and absorb the water jet energy [23].

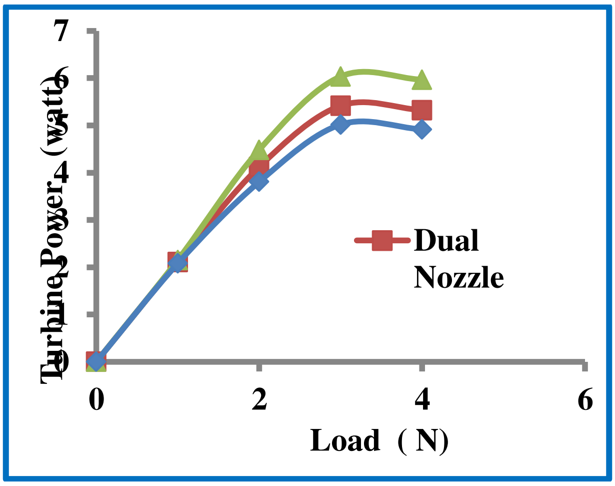

Figure-2. Turbine power towards the load variation graph.

In Figure-2 on it can be seen that the dual nozzle cross flow turbine has the best performance. The cross flow turbine power obtained by the 3 N load test at a constant discharge capacity for all load variation has best power produced, which is $P_{Turbine}$ = 6.04 Watt. The use of a dual nozzle on a cross flow turbine would generate a perfect water jet, more stable, so that it could produce and have a perfect power performance. The other advantage is that the discharge of water entering the turbine runner blades can produce an effective nozzle water spray, equitable water spray pressure distribution and the turbine blades could get an effective water jets impact. A single nozzle cross flow turbine with a horizontal positioned jet could just produce a maximum power of reaching 4 N, it is because the turbine rotation begun to decrease.

From this experimental study it is seen that the nozzle number and the nozzle position would strongly influence cross flow turbine performance. A cross flow turbine with a Dual nozzle would be able to increase the turbine power. It is because the blade number that could convert the water jet to the mechanical energy is higher [24]. While on the single nozzle cross flow turbine ether the horizontal or the vertical nozzle position has a lower

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performance. This is because of the water jet from the nozzle is not perfectly directed. The single vertical nozzle cross flow turbine has the lowest it efficiency, because there fewer turbine blade number driven by the water jet. $P_{Turbine}$ = 5.35 Watt. While for the cross flow turbine that uses a vertical single nozzle, could only produces a maximum power of $P_{Turbine}$ = 4.61 Watt. In general the use of dual nozzle, horizontal single nozzle and vertical single nozzle would increase the turbine power along with the increase of the turbine load. The turbine power would then decline when the maximum load

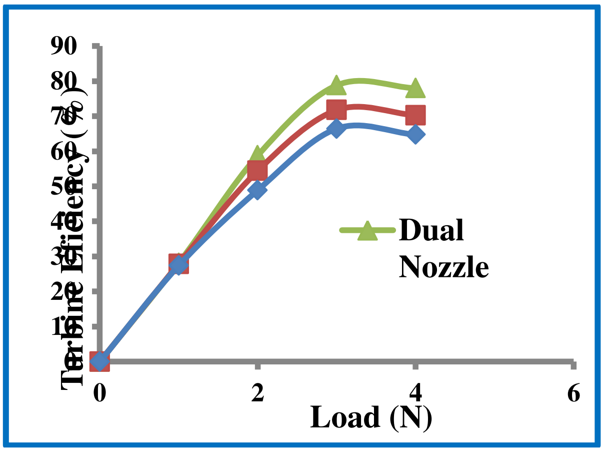

Figure-3. Turbine Efficiency Vs Load Variation Graph.

From Figure-3 it can be seen that the maximum turbine efficiency is obtained in the 3 N load test, and an efficiency of 78. 89%. While the cross flow turbine with a horizontal single nozzle has a lower turbine efficiency $\eta_{turbine}$ = 70.85%. The turbine cross flow turbine with a vertical single nozzle has the lowest efficiency $\eta_{turbine}$ = 61.95%, due to the power of water that can be absorbed and converted into a turbine blade turbine power is smaller. The turbine efficiency could reach the optimum value on the effective turbine operation, but at a time when the turbine was given the maximum load the turbine efficiency would then decrease as seen in Figure-3. The efficiency decrease is caused by the load that is greater than the turbine load ability and the turbulent water flow on the turbine, occurs reflection of water in turbine blades, water jets are not directed, flows into the turbine casing slit and against the direction of motion of the blades of the turbine [25].

5. CONCLUSIONS

The results of this research has been analyzed states that the dual nozzle Cross flow turbine has a better performance in generating power and has a higher efficiency, while the Cross Flow turbines with a single nozzle either with a horizontal nozzle or a vertical position has a lower performance.

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