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ORIGINAL ARTICLES

The Cross Flow Turbine Behavior towards the Turbine Rotation Quality, Efficiency, and Generated Power

[1]Jusuf Haurissa, [2]Slamet Wahyudi, [2]Yudy Surya Irawan, [2]Rudy Soenoko

[1]*Mechanical Engineering Doctorate Program, University of Brawijaya and Mechanical Engineering, Jayapura Science and Technology University, Jl. Raya Sentani Padang Bulan-Jayapura.*
[2]*Mechanical Engineering, University of Brawijaya, Jl. MT. Haryono 167, Malang.* (INDONESIA).

ABSTRACT

The focus of this research is the turbine flow behavior toward the turbine rotation quality, the turbine efficiency and the turbine power generated. The turbine rotation quality is really needed for the high quality electricity power generated. The method used in this research is the experimental method. The fluid flow behavior was observed by using a Casio 1000 handy camera and a Canon 550D camera. The data obtained from this observation is in a form of images and was completed with a data acquisition measurement (ADC). The result from the data collected and from the data processed shows that, the water flow comings out from the turbine first stage coming into the inner section of the turbine disc, would result a chaotic water flow. It is because of the water flow comings out from each turbine blade have their own direction. This condition, would ruin all the water flow direction, so that the water flow hits the second stage would probably hits the back of the blade, this would produce an unstable turbine rotation, and of course would reduce the turbine power (torque). Furthermore, by adding or attaching a guide passage with gate vanes to the second stage, the second stage power generated would almost optimum; this is because of the water flow angle entering the second stage would almost constant and always on the maximum condition. The water flow angle was forced to always at the exact maximum angle. The turbine torque would increase, the turbine efficiency would increase too and the turbine rotation would more constant and stable. This turbine stability will ended with a much better electricity quality. The turbine power without implementing the guide passage on the second stage produces a power of 22,608 watt. Furthermore, the overall turbine power by implementing the guide passage on the second stage produces power about 24,249 watt, and the overall turbine power by implementing the guide passage with gate vanes on the second stage produces power about 25.120 watt. So, there is a 2.215 watt (25,120 watt-22,608 watt) additional power produced, which means that there is a 10% power increase. The turbine efficiency without the guide passage is about 61.451 %, . Furthermore, the turbine efficiency using the guide passage is about 71, 236 % and the turbine efficiency using a guide passage with gate vanes, increase to 72.569%. Finally, there is an 11,118 % (72,569 % - 61,451 %) increase of the turbine efficiency.

Key words: Cross Flow Turbine, Flow Behavior, Power Turbine, Guide Passage, Gate Vanes, Turbine Blades, Efficiency Turbine.

Introduction

Recently, micro hydro become attractive because of its clean energy sources, renewable and has a good future development. However, the turbine type must be fit to the area conditions of the built turbine. The study or research against the effective and the relatively high production costs with a complex structure are the biggest obstacles to develop micro hydro. Turbine flow of latitude (Cross-Flow) is adopted because it has a relatively simple structure.

Previous studies for Cross Flow Turbine have been conducted by the researchers to determine the optimal configuration of the turbine using the experimental and numerical methods. Applying CFD is carried out to analyze the influence of the turbine structural configuration on the performance and the internal flow characteristics of cross flow turbine model (Cross-Flow). The results showed that the nozzle shape, runner blade angle and runner blade number is strongly associated with the performance and the internal turbine flow, where a layer of air in the turbine has a very important role in improving the performance of turbine (Yong Do Choi, 2008). Barglasan has used the theoretical analysis method of one-dimension and experiment. The previous

Corresponding Author: Jusuf Haurissa, Mechanical Engineering Doctorate Program, University of Brawijaya and Mechanical Engineering, Jayapura Science and Technology University, Jl. Raya Sentani Padang Bulan-Jayapura.
E-mail: jhaurissa@yahoo.com

research has also experimentally attempted to improve the performance of turbine by changing the shape of the output flow or by using tools on the turbine (A.V. Ramayya, 2006). Junicho Fukutomi, this study analyzes the flow of fluid that flows in a part of the runner, so that the turbine rotation becomes unstable. The research is experimentally and theoretically carried out for the determination of the fluid style on the latitude turbine blade (cross flow turbine). In the experiment, the tangential and radial force measured on the test blade using strain gauges and slip rings. Conversely, in a theoretical study, they are numerically calculated using the unsteady theory momentum. The results of studies in which the maximum force that occurred shortly before leaving the nozzle blade output was founded (Junichiro Fukotomi, 1995). Nakamura R. Fukutomi J, by installing vane guide of one sheet in the inside of the suction side, the performance of cross flow blade became more highly - pressured and highly efficient compared with no vane guide. The pre-rotation of flow inlet which has a different direction from the rotation of the rotor is caused by the vane guide. In the flow part, high pressure and high efficiency are obtained due to the emission of the work of suction flow increased with the flow pre-rotation, and because the separation of the primary side of the jet's sucking is more avoided at the high flow. In the low flow, it is possible to suppress the rotation flow in the round side of the inlet rotor suction. Thus, the high efficiency is obtained with the low power compared to the result without the vane guide (Junichiro Fukutomi, 2005). Barglazan M, developed a software to design a cross flow turbine, where several parameters must be entered and there are still some calculations to be performed where the results of these calculations must be entered into the software, however the addition of efficiency is not very significant (Barglazan, M., 2005).

While the research to be done is to analyze the flow behavior in the cross flow turbine runner, the turbine shaft rotation quality, the efficiency and the turbine power generated. The first step is analyzing the water flow entering the cross flow turbine in a normal turbine condition. The second step is analyzing the water flow passing through just into the first stage of the turbine. To control this condition a guide passage should be added to turn the water flow out from hitting the second stage turbine. From this observation, hopefully a result of the first stage turbine performance could be found. The third step is analyzing the water flow passing through just into the second stage of the turbine. To reach this condition a special nozzle could be attach in front of the second stage turbine, so that the water flow could get into the turbine second stage. From this step, it is expected a result of the second stage turbine performance. The objective of this last step is to find out, what is the best water flow angle to hit the second stage. The last observation would be a cross flow turbine with a guide passage, which would guide the optimized water flow angle, which will resulted a cross flow turbine with a higher performance and a more stable turbine rotation.

Materials and Methods

The schematic cross flow turbine used in this study are shown in Figure 1. Figure 1a, shows the ussual or original cross flow turbine design. In Figure 1b, is a cross flow turbine with an additional guide passage, as a result from this research. Finally, in Figure 1c, it is shown the cross flow turbine with a guide passage, and some more guide vanes to smoothen the water flows into the guide passage.

The turbine runner has three main parts, which is the turbine shaft, turbine disc and the turbine blades, which is made from stainless steel. The turbine blades was mounted around the turbine disc.

In this research, the turbine cover is made from a tranparent accryllic sheet. The whole turbine test bed was mounted with some parts that supports the research activity, such as a water storage tank, a centrifugal pumps to drain water from the reservoir toward nozzel, flow meters, brakes, pressure gauge, revolution counter transducer, ammeter, voltmeter, load adjustment knob, flow regulator valve, regulator handle and nozzle angle ADC serves to convert analog signals into digital signals. Flow Rate Scale, turbine rotation and torque generated will be recorded by a computer attach on the turbine test bed equipment (Autodesk Inventor Professional 2008).

Furthermore, the data taken from this study will be processed and would produces several charts and graphs to show the turbine performance phenomenon that occurred in this study. Dl is the outer runner diameter = 200 mm, the inner runner diameter Dd = 130 mm, rb is the turbine blade radius, which is 40 mm, the turbne blake thickness ts = 3 mm, the number of blades are 20, the nozzle area An is about 40 mm2, the guide passage has the same overall area with the nozzle area (Av = 40 mm2), the gate vanes radius are equal to the turbine blade radius rg = 40 mm and the distance between the turbine blades are 20 mm.

As mentioned above that in this study there will be a three steps observations. The first one is observing the indigenous cross flow turbine, without a guide passage. The second activity is observation using the a guide passage. The third observasion the using guide passage with gate vanes. The nozzle angle for every observation was variated, to get the best and optimized turbine performance.

Based on these three observasion, there will be another last test that will the optimized the turbine design. In this last step, it is expected a more efficient turbine and a more stable turbine rotation.

From the observation it is found that the best nozzle anggle $\alpha 1$ is about 16°, and the the best guide passage angle of the turbine is φ=18°. Based on these two nozzle angle datas a further test was done with variating the torque or shaft brake. The brake load was given at 1N (Newton), 2N, 3N and 4 N (Fig. 5).

To determine the turbine efficiency and turbine power, the test was done by maintaining the turbine cycle at a constant rotation 300 rpm. To keep the rotation constan at 300 rpm, a regulator is available control the water discharge. Furthermore, the same test was done on the load 2N, 3N and 4N as shown in Figure 2, 3, and 4. The data obtained was the turbine rotation, the water flow discharge, water pressure and the turbine torque.

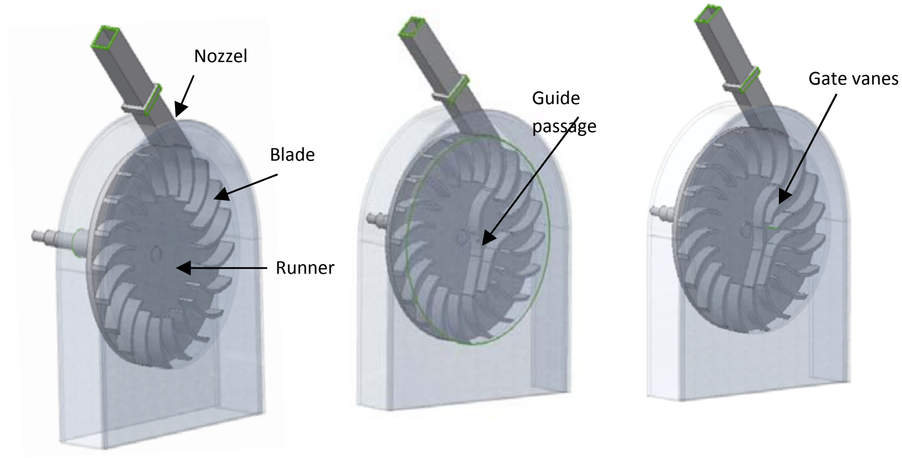

Fig. 1: Schematic cross-flow turbine test without a guide passage (a), Schematic cross-flow turbine using a guide passage (b), Schematic cross-flow turbine using a guide passage with gate vanes (c)

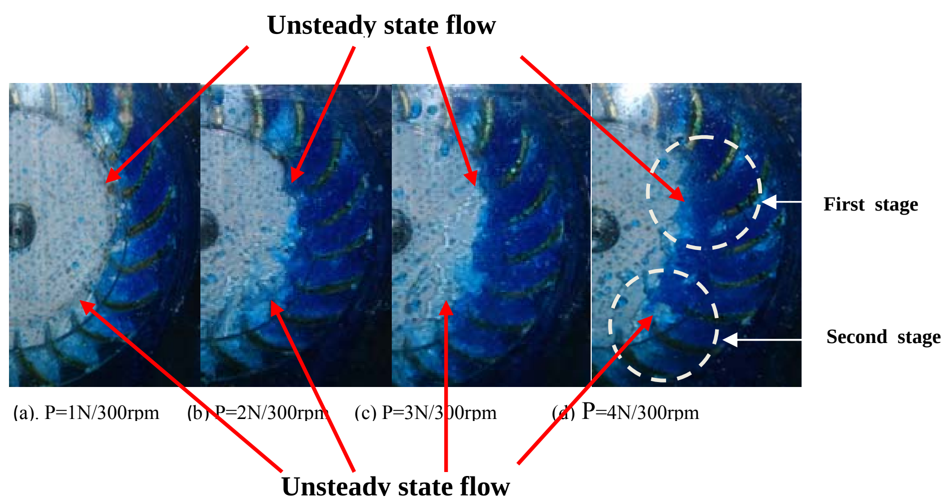

Fig. 2: Flow behaviors without a guide passage.

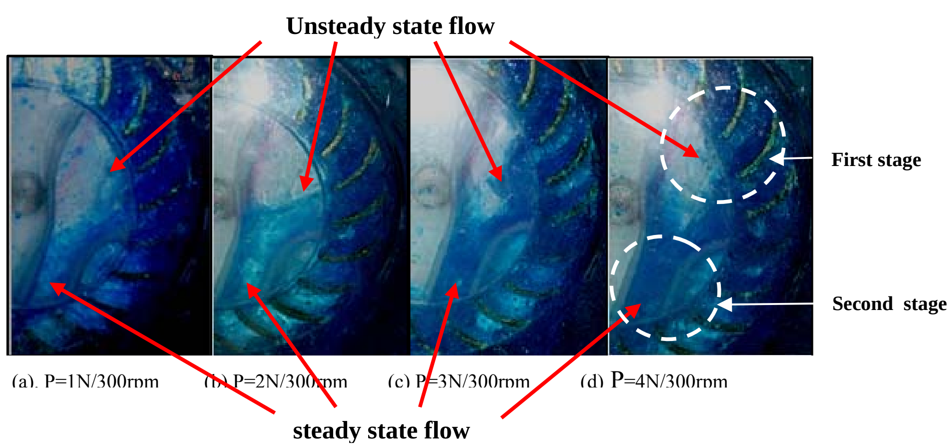

Fig. 3: Flow behavior using a guide passage.

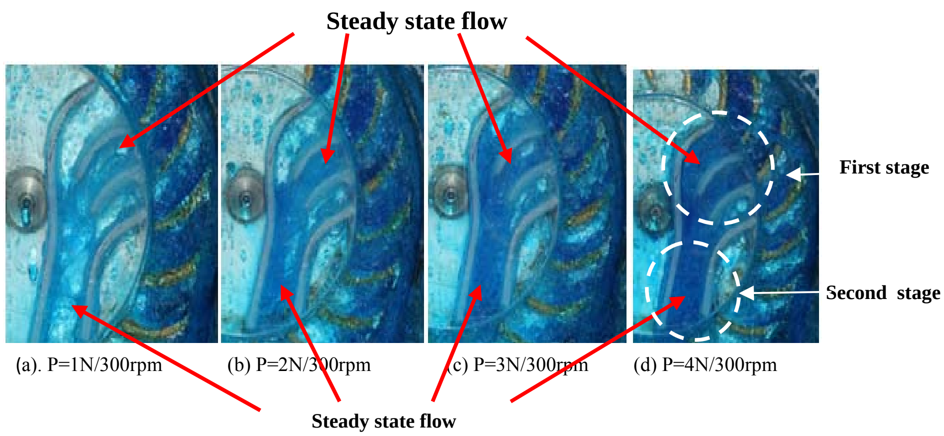

Fig. 4: Flow behavior using guide passage with gate vanes.

Results and Discussion

From the research result it is shown that not all of the water flow is following the water trajectory, it is caused by every water flow out from the turbine blade has its own direction. That is why every water particles tends to intersect in the middle of the turbine disc part as shown in Figure 2. The intersection phenomenon would ruin the water flow direction (Junichiro Fukutomi, 2005). The result of this chaotic situation would decrease the turbine rotation. After decreasing the disc rotation, the water direction would move into a correct direction again. Then the turbine disc rotation would increase again. This condition would repeat again and again, and would result an unstable rotation, shown in Figure 5a. In addition, the torque provided at this second level will decrease anyway.

Figure 3 shows the turbine flow behavior using a guide passage. At first, the water flows out from the first level would intersect, but the water flow was corrected by the passage and resulted that the water flow direction is going into the second stage with a correct direction. The turbine rotation would be more stable, as well as torque is being increase as shown in Figure 5b. From Figure 4 It can be seen that implementing a guide passage on a cross flow turbine would increase the turbine performance. The result was confirmed with similar works (Yong Do Choi, 2008; Junichiro Fukotomi, 1995). The turbine rotation would far more stable, and of course the turbine torque will increase as shown in Figure 5c.

On the observation of loading 1N, the water flow coming out from the first stage is very small (blue-colored fluid), this was due to the load given on the shaft will change the direction of water jet momentum on the turbine blades. Next to the loading of 2N, 3N and 4N, the water flow direction coming out from the first level will increase the water jet momentum. Data testing results is shown in table 1, 2.

From the graph in Figure 5a, 5b and 5c it is shown the most stable turbine rotation is shown in 5c, which is the cross flow turbine using a guide passage and gate vanes in it.

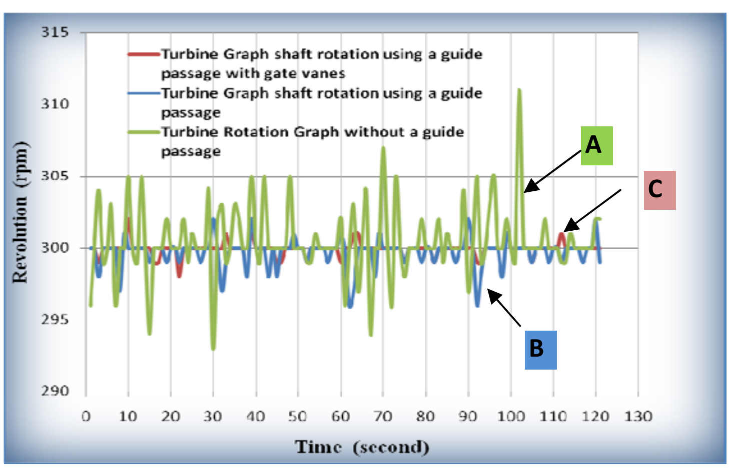

Fig. 5: Turbine Rotation Graph without a guide passage (a) Turbine Graph shaft rotation using a guide passage (b), Turbine Graph shaft rotation using a guide passage with gate vanes (c).

Furthermore, from the graph in figure 6, the highest efficiency is found in a cross flow turbine with a guide passage with gate vanes which is about 72.569%, with an efficiency differences of 11.118% (Table 1). In figure 7 it is shown that the highest power is about 25.120 watts, with a power difference of 10% or 2.512 watts. So, it is seen that at the same water flow rate there is a tendency of turbine power increase at every test with a constant turbine rotation of 300 rpm.

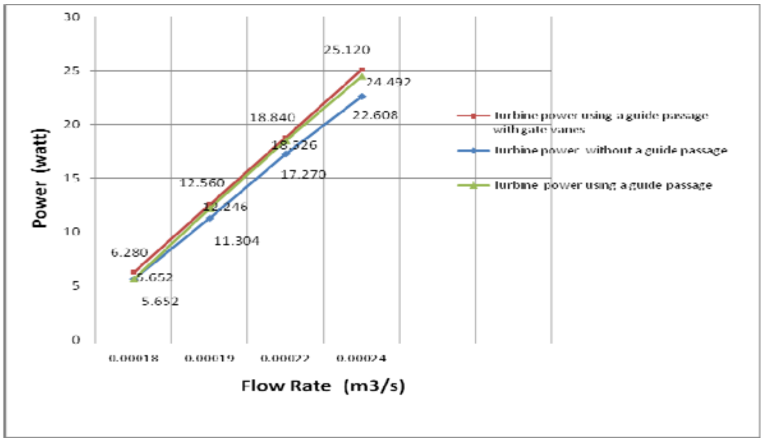

Fig. 6: Graph showing the relationship between Power (P) and flow rate (Q).

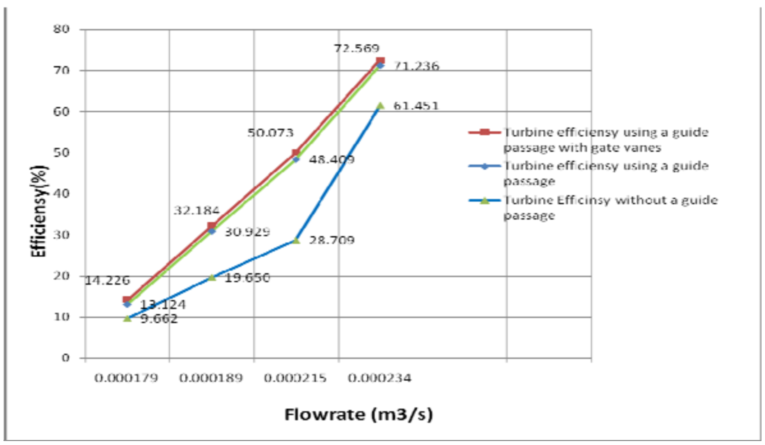

Fig. 7: Graph showing the relationship between Efficiency, Power (P) and flow rate (Q.

Table 1: Differences of Turbine Efficiency.

Working fluid	Total Efficiency (%)	Differences Efficiency (%)
Cross flow turbine using a guide passage	71,236	
Cross flow turbine without a guide passage	61,451	11,118 %
Cross flow turbine using a guide passage with gate passage	72,569	

Table 2: Differences of Power Outputs.

Working fluid	Total output power (watt)	Differences output power (watt)
Cross flow turbine using a guide passage	24,492	
Cross flow turbine without a guide passage	22,608	2,512 (10 %)
Cross flow turbine using a guide passage with gate passage	25,120	

Conclusion:

In conclusion. by installing a guide passage with some guide vanes as a nozzle to serve the turbine second stage, the water jet flow would exactly passes through the second stage blade with a precise angle. The turbine rotation would be more stable. This is important for the electric generation quality. The guide passage attach on a cross flow turbine would increase the turbine efficiency as big as 11.118%, and increase the turbine power by 10%. Nozzle guide vanes with a second level increase turbine efficiency of 11.118%, and increase the turbine power by 10%. It is seen that there is a tendency of turbine power increase at every test with a constant turbine rotation of 300 rpm.

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