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The Effects of Turbine Baffle Plates on the Efficiency of Water Free Vortex Turbines

Pongsakorn Wichian[a] and Ratchaphon Suntivarakorn[b*]

[a] *Farm Engineering and Automation Technology Research Group, Khon Kaen University, Khon Kaen, 40002, Thailand.*
[b] *Department of Mechanical Engineering, Faculty of Engineering, Khon Kaen University, Khon Kaen, 40002, Thailand.*

Abstract

This article is based on a study that focuses on increasing the efficiency of the water free vortex turbine by installing baffle plates on the propellers. In order to find the most suitable size and proportion for the baffle plates, the study used the CFD program to design baffle plates which have a diameter of 45 cm. and a height of 32 cm. The results showed that 5 baffle plates, with a propeller baffle area of 50%, gave the highest degree of torque. Propellers, with no baffle plates, were also created and were tested along with a turbine with 50% baffle plates at the flow rate of 0.04 – 0.06 m^3/s. The results showed that the propellers with a 50% baffle plate proportion helped to increase the torque at an average of 10.25% and with an average of overall efficiency of 4.12%.

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Keywords: Baffle Plates, Free Vortex Turbine, Turbine Efficiency

1. Introduction

Hydro energy is a natural resource with high potential for producing electricity. Hydro energy is a clean source of energy that does not create pollution to the environment. However, in order to produce electricity from water, it is necessary to build large dams which have an effect on the natural environment and are often opposed by the people in the area. Therefore, producing electricity from small water sources, such as rivers or streams, that have water flowing in them throughout the year, is an option that has currently piqued the interests of researchers.

* Corresponding author. Tel.: +66-4320-2845; fax: +66-4320-2849.
E-mail address: ratchaphon@kku.ac.th.

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There are two methods to generate electricity from small water resources as follows: 1. The Bypass Method: bypassing water from the main canal to a separate electricity generating system, and 2. The Open Canal Method: installing an electricity generator directly across the canal with no need for any additional structure.

Many researchers have studied generating electricity from small water resources, such as Wanchat and Suntivarakorn [1] who undertook to design the Free Vortex Electricity Generating System. From the study, a cylindrical whirlpool was designed with a hole at the bottom and water inflow was restricted to a tangential course so that the flow would imitate a tornado. In addition, a suitable water turbine was designed to be placed into the cylinder to generate electricity. Shabara, et al. [2] studied the important factors that affect the generation of electricity from the power generated from the water free vortex by using the CFD program. The results showed that at the highest water flow rate, the efficiency was at 40% at 28 rpm and 38 rpm.The result was in accordance to the study of Wanchat, et al. [3] in which the highest electricity generating efficiency was 35% at 40 rpm. Apart from research studies on the factors that affect the electricity generating efficiency from the power generated from the water free vortex, other researchers have also studied different methods to increase the electricity generating efficiency from power generated from the water free vortex. Dhakal, et al. [4] analyzed different basin structures and how they can create a water free vortex and the best water flow position in the basin that can increase the power of the turbine. The test results determined that a funnel basin was more efficient in generating electricity than the cylindrical type and that changing the materials used to make the turbine can also increase its electricity generating efficiency via the power generated from the water free vortex. Sritram, et al. [5] conducted a laboratory study on steel and aluminum, as the materials to be used to construct turbines in order to see how they affect the electricity generating efficiency from power generated by the water free vortex. The result was that the electric torque and the efficiency of the turbine made from aluminum was higher (8.4%) than the one made from steel (8.14%). In addition, modifying or installing accessories to the turbine can also increase its efficiency. Jeon, et al. [6] studied the effects of baffle plates on the efficiency of Savonius wind turbines by installing baffle plates at the highest and the lowest points of the turbine. This increased the efficiency by 36% when compared to the turbines without baffle plates. However, installing steel plates to increase the efficiency has only been studied on wind turbines.

From the information above, the researcher became interested in increasing the electricity generating efficiency from the power generated from the water free vortex by installing baffle plates to the turbine in a similar manner to the work of Jeon, et al. This was undertaken because it can be easily adapted, is not wasteful of the budget, and can increase the efficiency more than other methods. This article shows the details of the study and the tests on the turbines in order to find out how the installation of baffle plates on the turbine can affect the electricity generating efficiency of the water free vortex turbine.

2. Design and Efficiency of Turbine

2.1 Design of the Baffle Plate

This research used the CFD program to design the baffle plates. The program assisted the researchers in finding the appropriate design shape of the baffle plate to do the actual testing. The fluid used in this research was viscous with an incompressible flow. The equations used were the mass conservation equation and the momentum conservation equation with a k-ε standard Turbulent model. The details of the equation, that was used, were in accordance with the results of the study by Triputtarat [7]. The Bouyancy force equation was also used in the study.

The study simulated water flow at the mass flow rate of 60 kg per second, and the water head level was at 0.3 m. The water flowed through the propeller while the researcher conducted the study on which of the baffle plate shapes created the highest torque. From the study, a turbine was created using the CFD program for the actual testing.

2.2 The Torque and Efficiency of the Turbine

Finding the turbine torque was done by using the Prony Brake Absorption Dynamometer by installing it directly on the turbine's axle. The Prony Brake had an attached arm (L) that was 40 cm long. When the turbine

turned, the axle created the torque. The torque led to tension in the direction of the torque and scales (W). The equation used to find the torque from the turbine is shown in Equation (1).

$$\tau = W \times L \tag{1}$$

Power (P) generated from the turbine can also be found using Equation (2).

$$P = \frac{2\pi \times \tau \times N}{60} \tag{2}$$

N is the number of axle rounds (rpm). The efficiency of the turbine is found by the ratio of the actual power from the turbine by the power generated by the water. The actual efficiency of the turbine can be calculated using Equation (3).

$$\eta = \frac{P}{\rho g H Q} \tag{3}$$

p, g, H and *Q* are the water density, gravitation, water head, and water flow rate, respectively.

3. Equipment and Testing Methods

3.1 Testing Equipment

The study used a small hydro vortex power plant in the laboratory of the Department of Mechanical Engineering of Khon Kaen University. As shown in Figure 1 (a), a 1.5x1.5x1.2m water tank on top was connected to a cylindrical trough with a diameter of 1 m and height of 1 m. The water exit hole had a diameter of 0.2 m, and the water flow rate was able to be adjusted to 0.04 – 0.06 m^3/s by using the water pump. Two sets were used in the experiment which included the following: 1. with baffle plates installed on the turbine and 2. with normal steel plates with a thickness of 4 mm. as shown in Figure 1 (b) and (c).

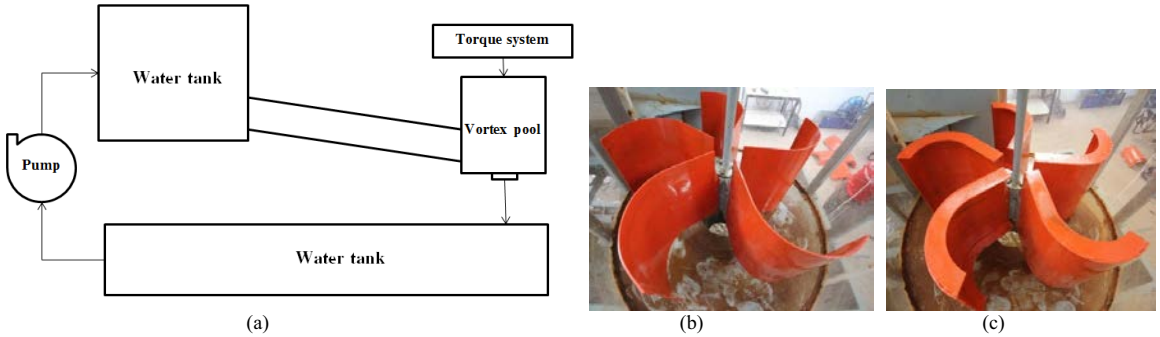

Fig.1. (a) Diagram of Electricity Generating System (b) Normal and (c) Turbine with baffle plates used in the experiment

3.2 Testing Method

The working process of the water free vortex system started with turning on the pump at the testing flow rate to pump water into the water tank. The water then flowed through the trough to the vortex pool. The torque, rpm, and water level were then measured when the turbine began to spin. The water in the vortex pool flowed through the exit hole at the bottom of the pool of the water tank. Then it was pumped back to the water tank on top to provide continuous flow throughout the experiment.

4. Results and Discussion

4.1 CFD Design Results

By using the CFD program, the results found the best number of propellers was between 3 and 6. Moreover, it was found that 5 propellers created the most torque which was in accordance with a study by Wanchat, et al. [3]. By studying the most appropriate number of propellers, an additional study was done on the proportion of the baffle plates from 0%, 25%, 50%, 75%, and 100% on 5 propeller turbines with a diameter of 45 cm and height of 32 cm. The results are shown in Figure 2.

	Model 1	Model 2	Model 3	Model 4	Model 5
Torque)N.m)	1.53	5.28	8.71	7.26	4.55
Proportion of baffle plate)%)	0	25	50	75	100

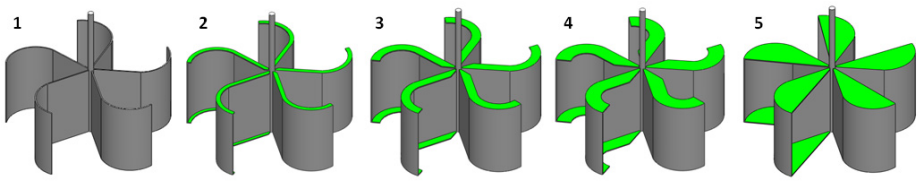

Fig.2. The Baffle Plates Installed on Turbines and Torque

From Figure 2, the 3rd model which had a proportion of the baffle plate of 50 % created the highest torque since partially blocking the propellers had helped in the storing of water mass because they came into greater contact with the propellers. As the momentum of the water impact increases, it leads to an increase in torque. However, if the proportion of the baffle plate is too great, too much inertia will be created and the torque will be reduced.

4.2 The Torque and Efficiency of the Turbine

The result of the CFD design was that turbines, having 5 propellers and having the proportion of baffle plates at 50 %, was the best design and created the highest torque. From the results, the researcher created and made a comparative test between a turbine with no baffle plates and one with 50% baffle plates . The tests were done at flow rates of 0.04, 0.05, and 0.06 m^3/s, and the results are shown in Table 1.

According to the test results in Table 1, turbines with 50% baffle plates were able to create the highest torque and were more efficient than any other flow rate with an average increase of 10.25% and 4.12%. This is in accordance with the CFD study.

Table 1. The Torque and Efficiency of the Turbine at Different Flow Rates

Flow Rate	Normal Turbine		Turbine with 50% of baffle plates	
(m^3/s)	Torque)N.m)	Efficiency)%(	Torque)N.m)	Efficiency)%(
0.04	27.21	25.68	30.87	27.91
0.05	32.44	30.92	35.58	31.78
0.06	42.12	37.88	45.78	38.68
Average	33.93	31.49	37.41	32.79

5. Conclusion

This research examined how to increase the efficiency of the Water Free Vortex Turbine by installing baffle plates on the propellers. The study was divided into the following 2 parts: 1. studying the number of propellers and the proportions of the baffle plates by using the CFD program, and 2. examining the results from the design to make a comparative test between turbines with and without baffle plates.

The CFD study defined water as a viscous fluid: incompressible flow by using the mass conservation equation and momentum conservation equation with a k-ε standard turbulent model, as well by using the buoyancy force in the simulation. The study results discovered that turbines with 5 propellers and 50 % baffle plates were able to create the most torque. Actual testing was made from the CFD design to compare the torque and efficiency between

turbines with no baffle plates and ones with 50% baffle plates at the flow rates of 0.04, 0.05, and 0.06 m^3/s. The results were that turbines, which had been installed with 50% baffle plates, had shown an increase in torque and average efficiency of 10.25% and 4.12%, respectively. Therefore, baffle plates can help to increase efficiency.

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References

[1] Wanchat S, Suntivarakorn R. Preliminary Design of a Vortex Pool for Electrical Generation. Advanced Science Letters 2012; 13: 173-177.
[2] Shabara HM, Yaakob OB, Ahmed YM, Elbatran AH, Faddir MSM. CFD Validation for Efficient Gravitational Vortex Pool System. Jurnal Teknologi 2015; 74: 97-100.
[3] Wanchat S, Suntivarakorn R, Wanchat SJ, Tonmit K, Kayanyiem P. A Parametric Study of a Gravitation Vortex Power Plant. Advanced Materials Research 2013; 805-806: 811-817.
[4] Dhakal S, Timmilsina AB, Dhakal R, Fuyal D, Bajracharya TR, Pandit HA, Amatya N, Nakarmi AM. Comparison of Cylindrical and Conical Basins with Optimum Position of Runner: Gravitational Water Vortex Power Plant. Renewable and Sustainable Energy Reviews 2015; 48: 662-669.
[5] Sritram P, Treedet W, Suntivarakorn R. Effect of Turbine Materials on Power Generation Efficiency from Free Water Vortex Hydro Power Plant. IOP Conference Series: Material Science and Engineering 2015; 103: 1-7.
[6] Jeon KS, Jeong JI, Pan JK, Ryu KW. Effects of End Plates with Various Shapes and Sizes on Helical Savonius Wind Turbines. Renewable Energy 2014; 79: 167-176.
[7] Triputtarat J. A Finite Element Method for Viscous Incompressible Flow Analysis. KKU Engineering Journal 2010; 37: 83-92.