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ENGINEERING AND EXPERIMENTAL STUDY OF PERFORMANCE OF VERTICAL AXIS WATER TURBINE IN JATILUHUR IRRIGATION FLOW

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Abstrak

This paper discusses the process of designing a vertical axis water turbine for the Helix Gorlov turbine model, to justify its effectiveness. The research was conducted through 2D computational studies, and experimental studies on Jatiluhur irrigation flow. Computational studies were carried out using the CFD-Numeca software. The theoretical study was developed, through simple programming using Matlab software, in relation to determining the theoretical power generated. Experimental studies were carried out with a vertical axis water turbine design process, both prototype and model scales. Through various studies in this research, such as hydrodynamic, structural mechanical, chemical and electrical studies, this research has been able to be carried out. The power produced in the experimental study process is 140 – 210 watts per turbine with a wet area of 1.2 m^2. The power generated is about 50% of the theoretical power of the Numeca 2-D simulation and 25% of the value of the 1-D theoretical study.
From this research, it is found that there is a real relationship between the design process and the experimental study. The realized turbine product is not in accordance with the design, making the effectiveness of the design turbine only 50% of the theoretical and computational study value.

Keywords: Vertical axis water turbine, Gorlov turbine, CFD-Numeca, Matlab, Power

1. INTRODUCTION

This paper discusses the process of developing a vertical axis water turbine (VAWT) carried out by researchers in completing the Government research program entitled "Design of Gorlov Water Turbine and Justification for Its Application for National Energy Sufficiency". The study was carried out through an iteration process of simulation and experimental evaluation of the VAWT blade design in relation to being able to build alternative power plants sourced from reliable water flow. The first prototype of VAWT which was carried out without going through in-depth theoretical studies has been able to produce electrical energy. The experimental test in the prototype stage carried out on the Jatiluhur irrigation flow is showing in Fig. 1’

a. Placement of VAWT on water flow

b. The light is on

Figure 1 Field studies carried out on the flow of the Jatiluhur irrigation system

Although it has produced quite encouraging results, namely producing electrical energy (as can be observed in Figure 1.b), but because of the low efficiency, researchers are trying to conduct further studies so that this equipment can be utilized in Indonesia. For information, the team has been conducting studies since 2004, stop in 2013 due the efficiency turbin and now start again. However, the success of conducting experimental tests has increased the team's enthusiasm to carry out more detailed studies and design improvements on all sides. The intended improvement is a change in profile and placement in the turbine system

The success of using turbine technology as a water flow energy conversion tool is highly dependent on the profile/airfoil of the blades and the configuration used. The study developed so far is the selection of basic airfoils, namely NACA0020. Studies have been carried out using Solid works software, and Numeca, to conduct 2-D to 3D studies. Turbine used 3 blades to avoid mechanical vibration problems, so that the blades were installed at an angle of 120 degrees between them. The turbine blade is twisted, as shown in Figure 2, which is intended to increase the absorption force, so that the resulting torque can be maximized [3].

Tidal (tidal) is produced by the earth's rotational force in the oceans as formed by the moon's gravity and the sun's gravity [1]. The moon's gravity causes tidal "attraction" which causes two "bumps" in the oceans on Earth (as shown in Figure 2). When an observer at a certain location on the earth rotates, this causes the local sea level to periodically rise and fall.

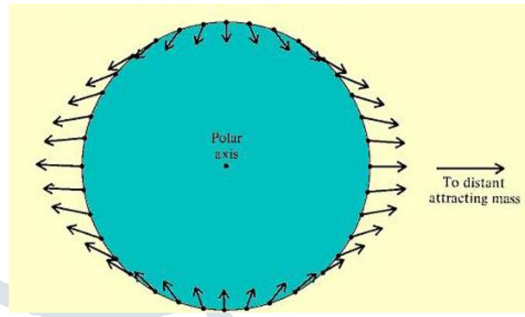


Figure 2 Tidal forces based on the interaction of the sun and moon [1]

Due to the non-uniform conditions of the earth, the tidal bumps that occur will be fragmented by the presence of continents and make them flow into various ocean basins, creating a more complex distribution. The distribution of the tidal bump pattern is shown in Figure 3.

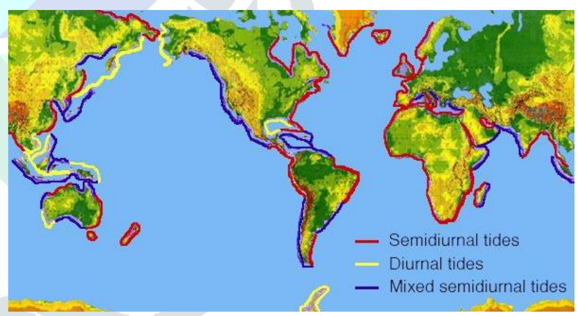


Figure 3. Tidal distribution [1]

The use of technology to absorb tidal energy, marine current energy and wind energy is in principle the same, namely using a turbine with an ideal blade [2]. This is because all three convert the energy of the fluid flowing around the turbine blades into rotational mechanical energy. The difference between the fluidity of water and wind is in their density, which for water is much larger (~800 times the density of air). Therefore, technology does not become very attractive to be a solution to the current energy shortage. The selection of turbine blade profile/airfoil in industrial applications is the most difficult aspect and often causes errors [3]. This is caused by the phenomenon of unsteady aerodynamics, in real conditions.

Because the flow pattern in real conditions varies in direction and magnitude, in this case the vertical axis is chosen. If the axis of rotation is perpendicular to the flow direction, it is generally known as a Cross Flow Water Turbine (CFWT) [4]. But in this study it is called the Vertical Axis Water Turbine (TASV). This type of water turbine has several advantages, although the prediction of its behavior is more complicated. In determining its performance, the study was carried out by using the CFD-Numeca software and simple programming in the MATLAB software.

Research that has been developed by several world researchers is still in the prototype development stage. This is related to studying their behavior, and the changes in characteristics that may occur. The investment costs are quite expensive and weather changes (tidal patterns) continue to be studied.

The purpose of the research developed is to utilize turbine technology, to be able to extract as much flow energy as possible, and realize it in rivers, straits and seas. This thinking is based on the fact that the more ideal the water flow pattern that is formed around the turbine blades, the maximum lift and drag that supports the occurrence of theoretical mechanical torque moments. Therefore, the blade used in this study is the NACA0020 which is twisted with a wavy field and a vortex generator. The generator used is the Ginlong generator with the GL-PMG-500A series, which is rated power 500 (W). This selection is based on a theoretical design study which gives a suggested 600 Watt result. It is based on the fact that the calculation results are always based on ideal conditions.

2. METODOLOGI

The theoretical torque value is calculated by multiplying the magnitude of the tangential force (Fr) by the distance from the capture point to the turbine rotation center, which is denoted by r. The value of the tangential force is determined based on the Hydrodynamic characteristics of the blade profile as written in Eq. (1). Thus the theoretical torque value can be written in Eq. (2). Theoretically, these equations are arranged based on the sketches in Figures 4 and 5.

$$F_r = q\,(c_l \sin(\gamma - \alpha) + c_d \cos(\gamma - \alpha)) \quad \ldots\ldots \quad (1)$$

$$T = r.F_r$$

$$= r.q.(c_l.\sin(\gamma - \alpha) + c_d.\cos(\gamma - \alpha)) \ldots\ldots..(2)$$

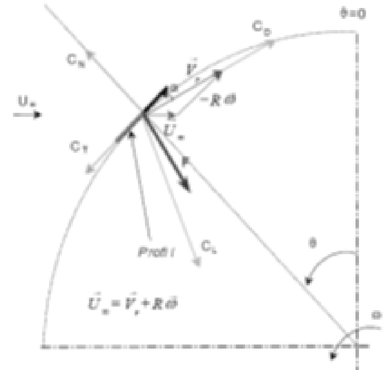


Figure 4 Forces at turbine blade [1]

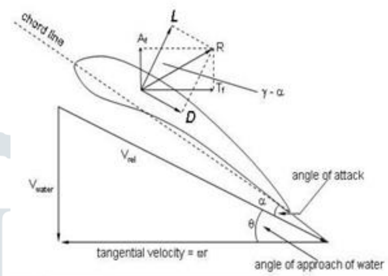


Figure 5 Force component [5]

The research was conducted at the Bandung State Polytechnic, both in the process of theoretical and computational studies as well as making models and prototypes for validation purposes. Experimental studies were carried out in Jatiluhur Krawang irrigation, to justify the actual conditions. This research was conducted from 2011 – 2012.

The test begins with determining the characteristics of the airfoil to predict the value of the torque moment and theoretical power that may be obtained. This is mainly related to determining the generator to be used so that it remains within ideal limits.

3. HASIL DAN PEMBAHASAN

The blade profile designed to be used in VAWT, was determined by observing the basic profile, its modification through bending, adding wavy fields and placing the vortex generator. This treatment has improved the hydrodynamic characteristics of the profile. From the results of a computational study by comparing the resulting torque values, the ideal basic airfoil used in VAWT is NACA 0020.

Numerical simulation using CFD-Numeca, to observe the dynamics of the water around the VAWT, it is possible to obtain an accurate and efficient VAWT design. The numerical simulation can be said to be a virtualization process from the experimental process, thus making the design process much more efficient and effective. As in general, Numeca CFD simulation, it is carried out under several flow conditions around VAWT, namely at several free stream velocity and at several VAWT rotational velocity. The numerical simulation results can be described in the form of a TASV performance curve which in the end can be concluded that the most efficient VAWT performance can be utilized. Examples of VAWT simulation results on CFD-Numeca can be shown in Figure 6 and Figure 7. It can be observed in the figure that the turbine shaft participates in providing additional thrust which in turn will provide a greater drag force.

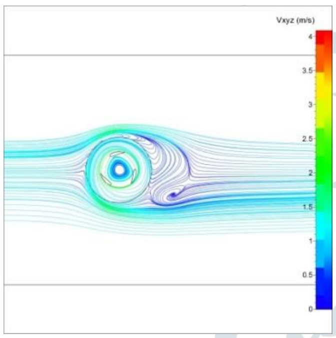


Figure 6 Streamline Pattern At 40% span wise Blade VAWT

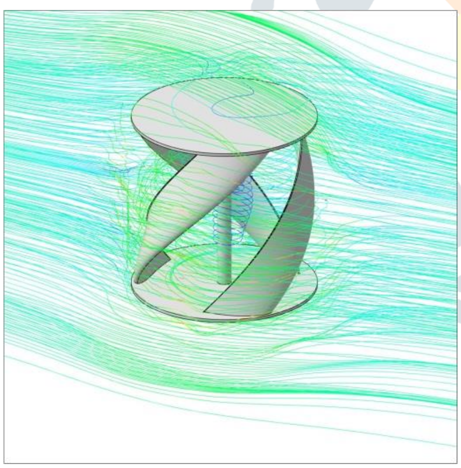
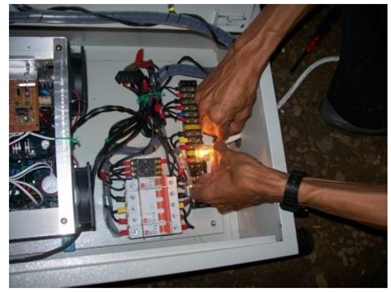


Figure 7 Streamline pattern of fluid flow around VAWT

The results of experimental studies carried out on the Jatiluhur irrigation water flow have provided around 140 – 210 watts of electricity. The amount is indeed too promising, but several improvements have been made and will be realized for further testing. The fluid flow at the time of testing was 1.2 -0.9 m/s, which is sufficient to contribute to why the power generated fluctuates. Photos of the tests carried out are shown in Figure 8.



a) Second field experimental

b) First field experimental

Figure 8 Field experimental result

Research on the conversion of water flow power to be able to rotate turbines efficiently can be carried out simultaneously, because the precision of the results of computational studies will be difficult to realize in prototype form, and in the research process. The electrical power produced will depend on two aspects, namely 1) how efficient the turbine is designed and 2) how efficient the generator is used. In the research discussed above, generators sold in the market are still used. Since the effective rotation is around 500 rpm, a gear box with a ratio of 1: 10 is used. This is based on a fairly low turbine rotation (~ 50 rpm). Thus, in future experimental studies, a generator designed by your self will be used.

4. CONCLUSIONS

In this study, the energy conversion of water flow into turbine rotation is quite effective and has been in accordance with initial estimates, which is in the range of 40-50 rpm. By using a generator that is on the market, and which is intended for wind turbines, the power generated is around 140-210 watts. The experimental result is 50% of the result on the 2D CFD computational study.

REFERENCE LIST

1. P´adraig Cantillon-Murphy, **Harvest-ing the Ocean's Energy : An evaluation of current trends in tidal and wave energy conversion**, Massachusetts Institute of Technology, Term Paper: "Sustainable Energy" 10.391J/22.811J/ESD.166J /11.371J/1.818J/2.65J/3.564J, April 28, 2005.
2. George Hagerman, Brian Polagye, EPRI – TP–001 NA Rev 3, **EPRI North American Tidal In Stream Power Feasibility Demonstration Project**, September 29, 2006
3. Khan, J., **River Current Turbine: Modeling and System Design**, Faculty of Engineering & Applied Science, MUN, St John's, NL A1B 3X5, December 2004.
4. James L. Tangler, The Evolution of Rotor and Blade Design, National Renewable Energy Laboratory, 1617 Cole Boulevard, Golden, CO 80401
5. Jeronimo ZANETTE, Didier IMBAULT, Ali TOURABI, FLUID-STRUCTURE INTERACTION AND DESIGN OF WATER CURRENT TURBINES, E-mail: Ali.Tourabi@hmg.inpg.fr, 2nd IAHR International Meeting of the Workgroup on Cavitation and Dynamic Problems in Hydraulic Machinery and Systems Timisoara, Romania October 24 - 26, 2007.