Designing the Horizontal Axis Shrouded River Current Turbine for The Experimental Purpose in Halu Oleo University

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DESIGNING THE HORIZONTAL AXIS SHROUDED RIVER CURRENT TURBINE FOR THE EXPERIMENTAL PURPOSE IN HALU OLEO UNIVERSITY

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Abstract

The clean renewable energy technology development should be on the top government program priority in present day, as the current energy availability and environmental challenges over the majority in the use of the unclean conventional power technologies. University has potential role to support the clean renewable energy development through research activities. This study deals with designing the clean renewable power technology based on a horizontal axis shrouded river current for experimental purpose in Halu Oleo University Indonesia. To fulfill this objective, some parts on the turbine unit are designed to be adjustable, thus, possibly making the process for the experiment. The method utilized in this study is the combination of literature review, mathematical model use, design and manufacture on the turbine. The result of this study is a unit of the horizontal axis shrouded river current turbine in which some of its parts, such as the shrouding device and the blade angle, are adjustable for the experimental purpose.

Keywords *: river, turbine, shrouding-device, experiment, energy*

Abstrak

Pendesainan turbin aliran sungai denagn saluran pengarah untuk tujuan eksperimen. Pengembangan teknologi bersih dan terbarukan seharusnya merupakan prioritas program pemerintah saat ini, didorong oleh kondisi tantangan energi dan lingkungan akibat penggunaan mayoritas energi berbasis sumber-sumber konvensional. Universitas memiliki peran yang sangat penting dalam mendukung upaya pengembangan teknologi energi terbarukan dan bersih melalui penelitian. Tujuan studi ini adalah untuk mendesain terknologi bersih dan terbarukan berbasis turbn aliran sungai horisontal dengan selubung untuk tujuan penelitian di Universitas Halu Oleo Indonesia. Metode yang digunakan dalam penelitian ini adalah kombinasi kajian literatur, penggunaan model matematika, pendesainan dan pembuatan turbin. Hasil penelitian ini adalah sebuah unit turbin aliran sungai horisontal dengan selubung, di mana beberapa bagianya, seperti parameter selubung dan sudut sudu, dapat diatur untuk tujuan ekperimen.

Kata Kunci: *sungai, turbin, selubung, eksperimen, energi*

1. Introduction

The economic development and the improvement on the standards of living are believed to have direct and indirect impacts on the energy usage (Nguyen, 2006). The electricity is a form of energy that has been extensively used by humans. This energy form has been accepted as one of the factors that drive the economic activities in all countries (Kaundinya 2009).

Indonesia is a developing country that has still challenge on the power sector. The electrification ratio in Indonesia is only around 67%. From this ratio, there are approximately 19 million people living with no power access, in which most of them in eastern part of Indonesia (ESDM, 2011).

According to Dasuki (2011), one of the factors inhibiting the electricity distribution is the characteristic of geography and topography in Indonesia. This country comprises not only many islands, amounting to nearly 17,500, but also has a mountainous and hilly land characteristic. This condition requires the high costs for the power distribution. The sustainable alternative power technology using local sources can be one of the solutions in addressing the problems of the electricity distribution. This is because the technology can be operated closer to the user with locally available fuel sources. In addition, some of these energy forms are more environmentally friendly than those of the power based on the conventional sources (Zand 2009).

The power system based on the river flow is among the alternative clean renewable decentralized energy technologies. One of the advantages on the use of the river stream power is the higher power density to wind energy (830 times on the same dimensions and velocity). Thus with the same capacity, the dimensions of the water turbines will be much smaller than that of the wind turbines.

One of the constraints on the use of the river stream turbine technology is the low efficiency. This is because that the energy conversion mechanism of the turbine is based on only the kinetic stream power, with almost no head. However, the incorporation of the shrouding device is believed to enhance the turbine efficiency.

Halu Oleo University, situated at Southeast Sulawesi, a developing region in eastern part Indonesia, has potential role to support the development on the alternative energy power based on the water stream, through the research activities. This study focuses on designing a horizontal axis river current turbine incorporated with the shrouding device for experimental purposes in Halu Oleo University.

2. Literature Studies

Potential hydropower in Indonesia

Water is a natural resource essential for the life on earth. It is believed that more than seventy percent of the earth's surface is covered by water, accounting around 1.4 trillion cubic kilometers. Indonesia is a nation which has abundant potential of water. It is not only the majority of the region is water, caused by the existence of many islands, but also there are many mountains, rivers and forests in many of its regions. This condition potentially supports the development of the power generation technologies based on the water current. Indonesia is believed to have the potential for the river-based energy, totaling 75 GW (D Hayes, 2004).

Horizontal turbines

Horizontal axis turbine is one of the power conversion machines that have advantages of the higher efficiency than that of the vertical turbines. Indeed, the force experienced by the horizontal turbine blades is more uniform than the vertical blades, thus the cyclic load for the horizontal blades would be less (Alidadi 2009).

Many works have focused on the development of the horizontal turbines. In 1978, Peter Garman develops a river flow turbine with the horizontal blades. The turbine is claimed to have been used successfully for the energy source of the irrigation pumps in the countryside areas in the Nile, in Egypt, Sudan and Somalia. The following work on the turbine, named as the Garman-Turbine, is utilized to generate electricity (Anyi, 2010). In 1994, the Marine Current Turbine Corporation in the UK conducts an experiment on the horizontal axis river current turbine in Loch Linnhe, Scotland (Anyo, 2010). The Alternative Way Company in Nimbin, Australia, develops a horizontal turbine, known as Tyson Turbine. This turbine is placed in the river with the mechanism of transmission of 90 degrees (Levy D, 1995). The University of Brasilia develops a 6 blade-horizontal turbine with 0.8 meter diameter that generates 1 kW-AC power. The turbine has been utilized as the power source for lighting and refrigerator at a health center in Bahia Brazil (Anyi, 2010).

Shrouding device

Technically, the horizontal axis turbine has maximum efficiency of only 0,59, known as the Betz limits. The incorporation of the shrouding device into the turbine is believed to improve the performance (Ponta 1999) (Lawn 2003) (Rom & Bowen 1998). According to Khan (2009), the shrouded device induces low pressure of fluid in the rear region, which increases the amount of the fluid flow into the turbine.

In a theoretical study by Riegler (2000), it is shown that the efficiency of the shrouded turbine is 1.96 to 3.3 times to the Betz limits (Alidadi M, 2010). The improvement on the turbine efficiency is also found in the theoretical study on the turbine with shrouding device in Lawn (2003) and Rom (1998). Ponta (1999) develops a water turbine with the shrouding device. By using a test on a canal, it is shown that the addition of the device improves the turbine performance.

Mathematical model of turbine with shrouding device

The mathematical model to predict the performance of the turbine with shrouding device can be found in Rom (1998) and Lawn (2003). In these models, the power of the turbine is formulated by

$$P = 0.5\,\rho\, V_0^3\, A\, K \left(\frac{2}{K-\left[\frac{D_1}{D_3}\right]^2}\right)^{\frac{3}{2}} \qquad (1)$$

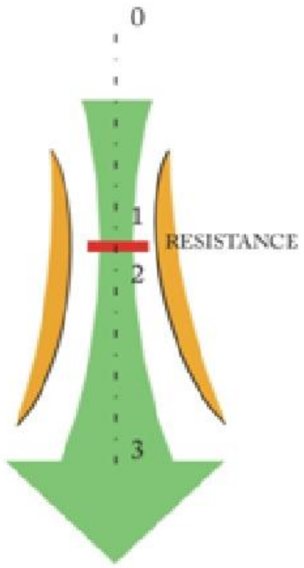

Figure 1. Model of turbine with shrouding device (Source: Rom 1998 and Lawn, 2003)

Where K is the coefficient of resistance, D_1 is diameter of throat (narrowing position) in which the turbine is placed and D_3 is the width of the shroud in rear region (see figure 1). This model is based on the assumption that there is no separation of fluid on the walls of the shroud. In addition, the decrease in the static pressure between the area at free stream (0) and at downstream (3) is equal to the kinetic pressure at the free-stream area (0).

The model to project the performance of the shrouded turbine considering the blade geometry can be obtained in Rachman (2010). In this model, the power of the turbine is formulated by

$$P = \int_{\lambda rh}^{\lambda R} \left(\frac{B\,c}{2\,\Pi\, r}\right) \left(\frac{2}{K - [\frac{D_1}{D_3}]^2}\right) (\Pi\, R^2)\rho\, \frac{{V_0}^3}{(\sin\varphi)^2}\, C_L \sin\varphi \left(1 - \frac{C_D \cos\varphi}{C_L \sin\varphi}\right) \left[\frac{\lambda_r}{\lambda}\right]^2 d\lambda_r \qquad (2)$$

Where λ is the tip speed of the turbine, λ_R is the tip velocity at the outer end of the blade, λrh is the tip speed of the blade at the end, B is the number of blades, c is the width of the blade, R is the radius of the blade, φ is relative fluid angle, C_L is the lift coefficient of turbine blades and C_D is the thrust coefficient of turbine blades.

The Coefficient of Performance (CP) is defined as the ratio of the turbine power to the available water current energy.

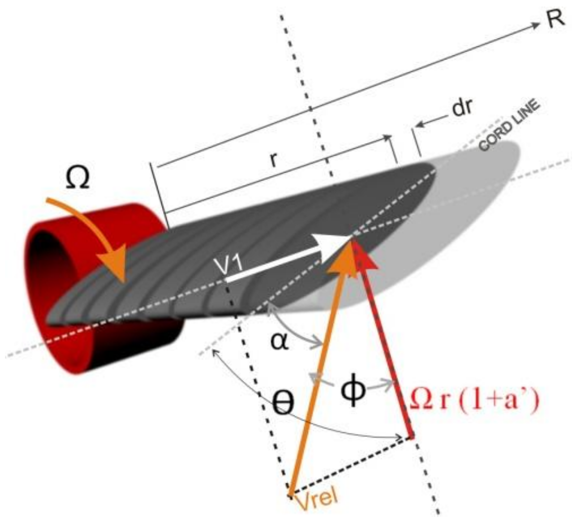

Figure 2 The model of turbine blade in case of shrouding device

The relationship between the coefficient of resistance and the blade geometry can be obtained as following equation

$$\left[\frac{2}{K-\left[\frac{D_1}{D_3}\right]^2}\right] = \frac{B\, c\, V_{rel}{}^2 (C_L \cos\varphi + C_D \sin\varphi)}{V_0{}^2\, 2\, \Pi\, r} \qquad (3)$$

The blade angle (θ) is defined as the angle between the line cord to the line rotation turbine and always satisfies the following equation,

$$\theta = \alpha + \varphi \qquad (4)$$

The parameter of α is the angle of attack, which is the angle between the relative velocity to the cord line. This value is the function of the lift and drag coefficients of the cross section of the blade.

3. Research Methodology

The methodology of this study is to design a river current turbine with shrouding device for experiment purposes. Some proposed parameters in this experiment device are the shape-geometry of the shrouding device and the blade. For the shape-geometry of the shrouding device, the proposed parameter is the diameter ratio of front-rear diffuser. For the aspect of the blade geometry-dimension, the proposed parameter is the blade pitch angle.

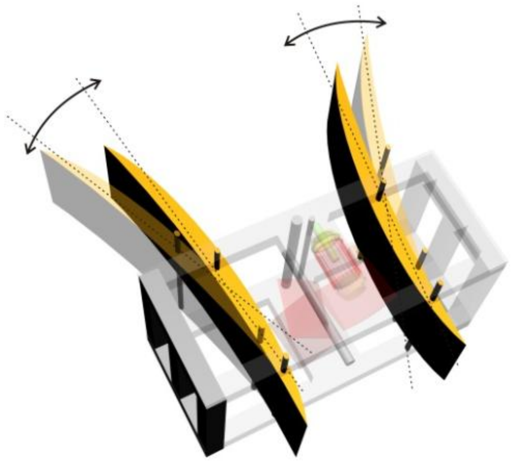

Figure 3 The shrouding diameter ratio adjustment

The selection for the parameters is based on the equation (1) and equation (2).In the system of shrouded river flow turbine, based on the equation (2), some of the parameters that determine the performance are the coefficient of resistance and the diameter ratio on the shrouding device. Thus, in designing the experiment device, the parameters of the coefficient of resistance and the ratio of the inlet-outlet diameter of the shrouding device enable to be varied

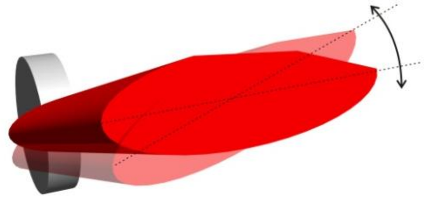

Figure 4 The blade pitch angle adjustment

The coefficient of resistance is the function of the turbine blade angle. Thus in the design of experiment machine, turbine blade angle should be enabled to be adjusted. Based on the equation (4), when the blade angle (θ) is changed, the angle of attack (α) and the relative angle (φ) changem thus it changes the value of the resistance coefficient and the performance (see equations (3) and (2)).

4. Results

Result of this study is the horizontal axis river current turbine with a channeling device for an experiment purpose. The experiment that can be done with this device is the influence on the blade angle and the ratio of the inlet-outlet shroud diameter to the performance of the river flow turbine with the shrouding device.

Figure 5 Design of river turbine (1)

Figure 6 Design of river turbine (2)

The basis of the selection of parameters is the mathematical models developed by Lawn (2003) and Rachman (2010). From the mathematical models, it can be clearly seen that, the ratio of the inlet-outlet shroud considerably affects the performance of the turbine. In following paragraph, it explores the effect on the ratio to the performance using a parametrical study of the models. It uses the MATLAB program to assist the calculation. Into the models, the inputted parameter for the water velocity is 2 m/s. The number of blade is set to be 3 at 0.6 blade m-diameter with hydrofoil type of NACA 2415. The pitch angle is set to be 12^o and the tip speed is varied from 0 to 20.

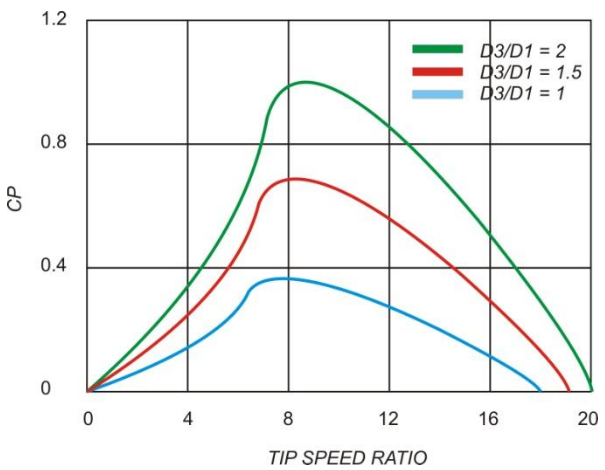

Figure 7 Parametrical study on the effect shrouding device ratio

From the results of the parametrical study, it is shown that there is a significant change on the performance when the diameter ratio of the shrouding device is changed.

In following paragraph, it explores the effect of the blade pitch angle to the performance using a parametrical study on the models. Into the models, the inputted parameter for the water velocity is 2 m/s. The number of blade is set to be 3 at 0.6 m-diameter with the hydrofoil type of NACA 2415. The tip speed is varied from 0 to 20.

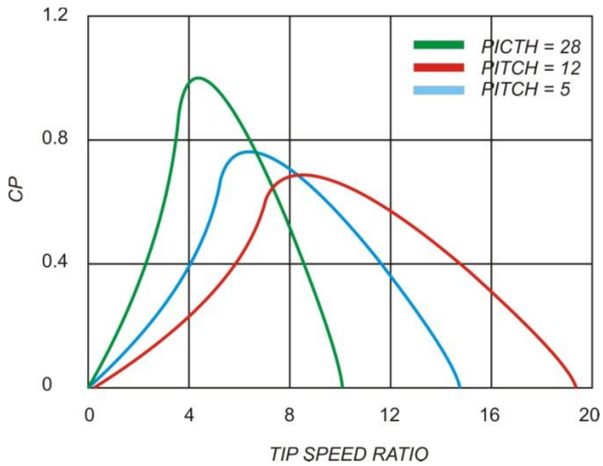

Figure 8 Parametrical study on the effect of pitch angle

It looks very clear from the results that the correlation between the angle of the blade and the turbine performance is so obvious. When the blade angle is changed, the performance changes as well

5 Conclusion

A unit of river current turbine with shrouding device for an experiment purpose has been designed. The design of the unit enables the users to conduct the hydrodynamic performance test on the variation of the blade pitch angle and the diameter ratio of the shrouding device. The proposed parameters are based on the mathematical models of the water current turbine with channeling device. In the next work, the experiment on the river of using the unit and the comparison to the models will be conducted.

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