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DEVELOPMENT OF VERTICAL AXIS MARINE CURRENT TURBINE FOR SUNDA STRAIT APPLICATION

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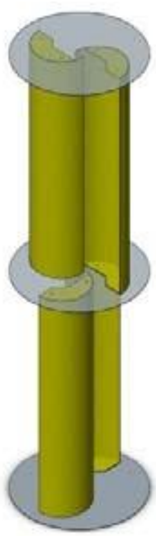
Graphical abstract



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Abstract

The development of Renewable Energy (RE) has become one of the priorities that has been promoted by various governments around the world, as a step towards implementing green energy in accordance with the Paris Agreement. The sea as one of the largest parts of the territory in Indonesia must be managed for its energy because it has quite large energy potential. One of them is ocean currents. The Sunda Strait is a very strategic strait and has ocean currents that have the potential to develop energy to be used as a source of electrical energy. Therefore the development of a suitable turbine design is urgently needed in this strait area. In previous research the simulation and experimental work have confirmed that the Savonius rotor can be worked in the low speed marine current. This is will be relevant with Sunda Strait condition that have current 0.4 – 1 m/s. The experiment also shows that the rotor provided torque 0.36 Nm with 11.97 RPM therefore can generated 0.45 Watt.

Keywords: Marine current energy; Marine current turbine; Sunda Strait

Abstrak

Pengembangan Energi Baru Terbarukan (EBT) menjadi salah satu prioritas yang telah diusung oleh berbagai pemerintahan di seluruh dunia, sebagai langkah perenerapan energi hijau sesuai dengan Paris Agreement. Laut sebagai salah satu bagian wilayah yang terbesar di Indonesia harus dikelola energinya karena mempunyai potensi energi yang cukup besar. Salah satunya adalah arus laut. Selat Sunda merupakan selat yang sangat strategis dan mempunya arus laut yang berpotensi dikembangkan energinya untuk digunakan sebagai sumber energi listrik. Oleh sebab itu pengembangan design turbin yang sesuai sangat diperlukan pada Kawasan selat ini. Pada penelitian sebelumnya, simulasi dan eksperimen telah mengkonfirmasi bahwa rotor Savonius dapat bekerja pada arus laut kecepatan rendah. Hal ini akan relevan dengan kondisi Selat Sunda yang memiliki arus 0,4 – 1 m/s. Eksperimen juga menunjukkan bahwa rotor memberikan torsi 0,36 Nm dengan 11,97 RPM sehingga dapat menghasilkan 0,45 Watt.

Kata kunci: Energi arus laut; Turbin arus laut, Selat Sunda

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1.0 INTRODUCTION

The recent increase in the price of crude oil has reminded many quarters on the transient nature of fossil fuel. On the other hand, environmental issues are forcing governments to consider the incentives for development of alternative clean sources of energy. One of the potential sources of clean energy is the ocean. In this respect, a number of initiatives are being pursued by various governments, such as New Zealand [1], United Kingdom [2], Australia [3], European Union [4], the United States [5,6] and Japan [7].

Indonesia as an archipelagic country has around 17,805 islands with an estimated area of more than 5.4 million km2 where 2/3 of its territory is sea with a total coastline length of 81 thousand km, this makes Indonesia the second longest after Canada. With this condition, of course, places Indonesia as a country that has the greatest potential for marine energy in the world.

Ocean energy is a source of energy that is produced from various natural movements in the oceans using methods and technologies that are continuously developing. The process of producing marine energy does not cause CO_2 emissions so it is very environmentally friendly and a source of renewable energy (green energy). Theoretically, the amount of ocean energy is around 1.8 TW, so it becomes a large enough energy source considering that 70% of the earth's surface is sea. Therefore, Indonesia with the largest area is the sea, so this energy source is quite abundant in this country

Tidal Ocean Currents, which originate from the movement of the tides caused by the gravitational forces of the sun and moon. This movement will produce ocean currents which have kinetic energy that can be used to drive the rotor in the turbine. After that the turbine is connected to a generator so that it will produce electricity. This turbine will be in the sea and can be installed in many places.

Research results from the Marine Geology Research and Development Center (P3GL) show that Indonesia has a potential for tidal currents of 18 GW, sea waves of 2 GW and OTEC of 41 GW, so the total potential is 61 GW. Of these three sources of energy, ocean currents have the greatest potential to be used. This is because it is predictable, the mechanical process is not complicated, and it is located in a non-coastal sea area so it is safe from population problems or social issues.

There are several studies of tidal currents that have been conducted by several researchers related to the energy of these tidal currents. Orhan, et., al (2016) describes its energy potential when using a current speed of 0.5 m/s as shown in Table 1 below. In this table, the largest energy is found in the Alas Strait, which is 2.258 GW, while the Sunda Strait is 335 MW [8].

The Sunda Strait is a potential place to be developed as a location for tidal marine energy. Even though it is not the greatest potential, but with a very strategic location between the most populous islands in Indonesia, the island of Java and the island of Sumatra, it is an added value that can make its economic value high. This is because the national transmission system already exists both on the island of Java and on the island of Sumatra. With the existence of New and Renewable energy in this area, of course in the future it can be an alternative to replace the role of fossil energy that currently exists.

Table 1. Energy map of tidal currents in the straits of Indonesian territory [8]

Strait	Density Energy	Power Plant Energy	Total Energy
Bali	14.75	1,459	1,045
Larantuka	10.20	1,25	299
Boling	3.49	430	736
Alas	3.07	396	2,258
Lombok	2.36	236	865
Sunda	1.56	165	335
Badung	1.52	161	551

The development of turbines in the Sunda Strait area will certainly be an example of their use in other straits in Indonesia. This is because the Sunda Strait is very close to research centers from both BRIN or universities in Indonesia and of course it is close to the center of government, so it has the potential to focus on becoming a Tidal Ocean Current Turbine research pilot project.

The side of the Sunda Strait that can be developed is the sea area of Sangiang Island (Merak, Banten). Sangiang Island is located near the port of Merak. In one of the studies of the tidal currents of Sangiang Island, it was found that the speed of the ocean currents reached 0.4 - 1 m/s. Figure 1 shows the sea area of Sangiang Island which has the potential to install Tidal Current Turbines [9].

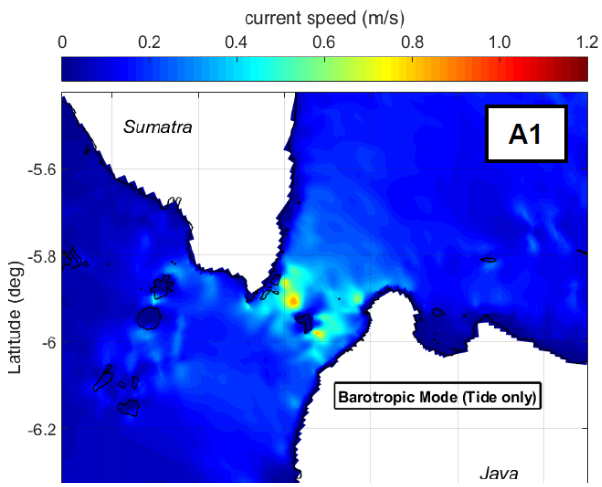

Figure 1. Simulation Tidal current speed at Sunda Strait

Currently, marine current energy is being harnessed using two types of turbines; vertical axis marine current turbines (VAMCTs) (reference [10- 13]) and horizontal axis marine current turbines (HAMCTs) (reference [14-16]). Reference [17] also briefly describes and classifies some of the most common VAMCTs being currently developed. Some of the potential turbines are tabulated in Table 2.that shows that the existing VAMCTs are mainly developed for current velocity greater than 1.1 m/s (2.45 knots). Unfortunately, Malaysian sea current velocity is much lower averaging only about 0.56 m/s or 1.1 knots [18].

Table 2. Environmental factors, vessel parameters and other factors [19]

Vertical Axis Turbine	Operational Current Speed [m/s]
Darrieus	1.1
Helical	1.5
Kobold	1.8
Davis	2.5

2.0 ROTOR TURBINE

Based on Sunda Strait current condition 0.4 m/s – 1 m/s, this will be categories low current speed. From this condition, type of turbines in Table 2 are not working optimum due to the current speed below of operational current speed.

One potentional type of turbine is Savonius turbine that can work in low speed current. Being a drag-based rotor, it has the potentials to capitalize on the higher density and viscosity of seawater. The findings of this study can be found in reference [19]

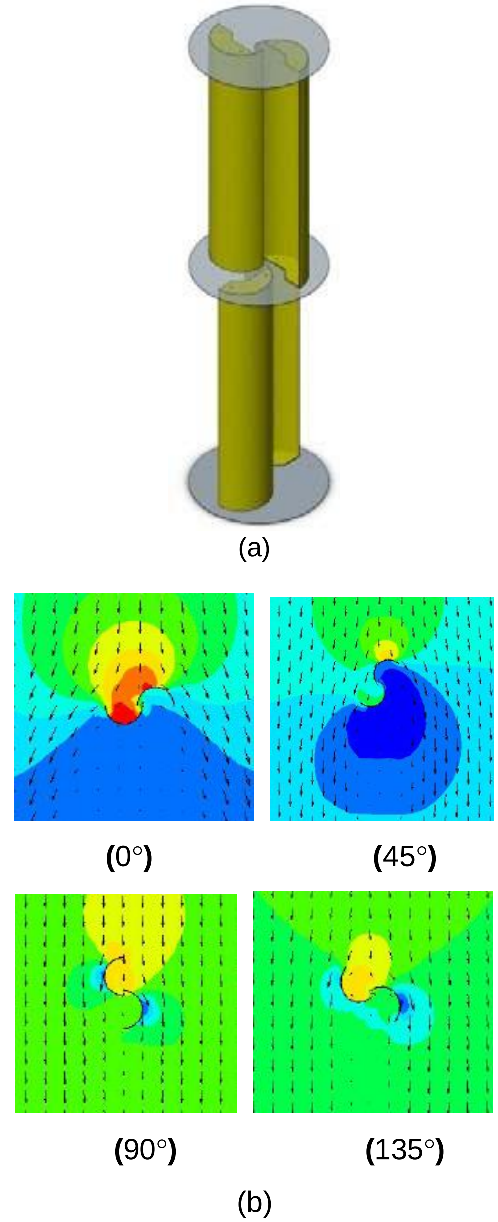

Figure 2. (a) Savonius Rotor, (b) CFD simulation result [20]

Figure 2 show about the Savonius turbine that have optimation using CFD sofware (COSMOSFloworks) to provide high pressure with considering stacking and overlap ratio configuration. The simulation run in 0.17 m/s and have indication the turbine will have the pressure in the paddle (blade of turbine). The pressure indication can estimate the the turbine can rotate in this low speed current. This condition will be proved by experimental work. Table 3 show the dimensions of the turbine simulation.

3.0 DISCUSSION

This simulation study have done that shows vertical axis Savonius turbine has good potentials for low marine current velocity application. The most recommended overlap ratio for this type of turbine is β = 0.21. This is similar to the results of studies on Savonius turbine for wind turbine applications. This study also shows that the actual torque behaviour of this turbine is sinusoidal in nature and their values are always positive, showing this kind of turbine is suitable for mechanical application [19].

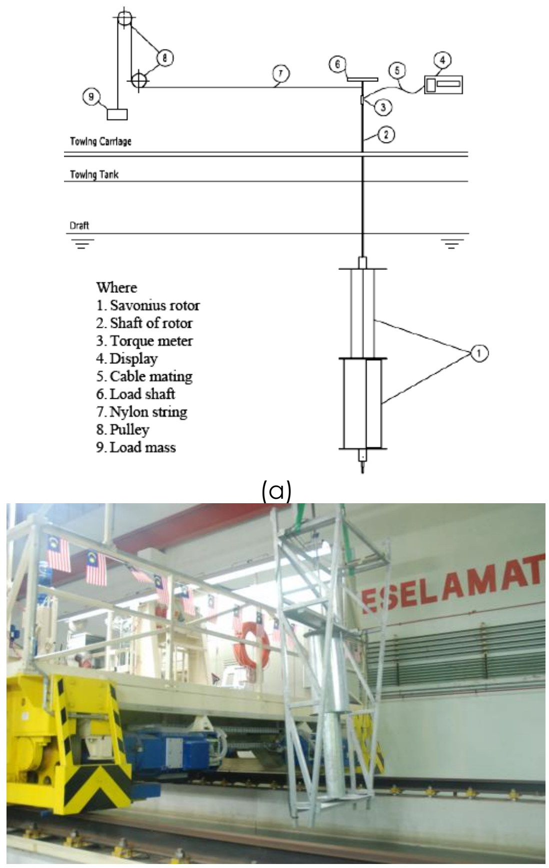

Figure 3. (a)Schematic representation of model experiment at rotational condition; (b) Experiment of Savonius rotor

The experimental was generated in the towing tank in Marine Technology Laboratory, UTM, which had 120 m length, 4 m breadth and 2.5 m water depth. The model was towed at speeds equivalent to the required marine current speeds while the torque and RPM values were measured. A torque meter was put on top of shaft to measure torque (Nm) and angular velocity (RPM). The experiment was run at two conditions; static and rotational conditions. Figure 3 shows the experiment schematic with towing carriage.

Figure 4 shows the performances of Savonius rotor of experiment. The maximum angular speed is 11.97 RPM and torque to make the rotor stop is 0.36 Nm based on CFD simulation with overlap ratio 0.21. Table 3 also show the result of experiment as torque and angular speed.

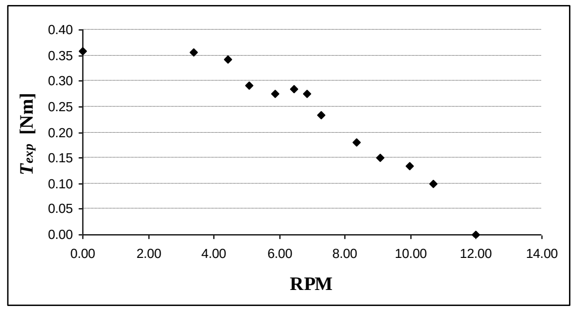

Figure 4. Torque and RPM of experiment overlap ratio 0.21, Vm = 0.17 m/s

Table 3. Dimensions and condition for model simulation

Dimension	Value
Height of rotor, H_m	1.5 m
Diameter of paddles, d_m	0.375 m
Nominal velocity, V_m	0.17 m/s
Torque, T_{exp}	0.36 Nm
Angular speed [RPM]	11.97 RPM
Power, P_p [Watt]	0.45 Watt

The experiment was conducted to provide performance of turbine. The performance parameters of the turbine such as coefficients of torque (Ct), tip speed ratio (λ) and coefficient of power (Cp) can be obtained from the experimental results. The parameters are calculated using Equations (1, 2 and 3) :

$$C_t = \frac{4.T}{(\rho.V^2.D^2.H)}$$

$$\lambda = \frac{\omega.r}{V_m}$$

$$C_p = C_t.\lambda$$

From the above equations, performance of the turbine can be found as shown in Figure 4. The maximum Cp of the turbine is quite low, just below 0.16 at the tip speed ratio (λ) of 0.79. Nakajima et al. [15] also carried out experiments on the Savonius turbine with horizontal axis. The result of the coefficient of power (Cp) was higher than vertical axis turbine. However, the overlap ratio of the cross-flow turbine was 0.36 compared to the overlap ratio of 0.21 used in the present study.

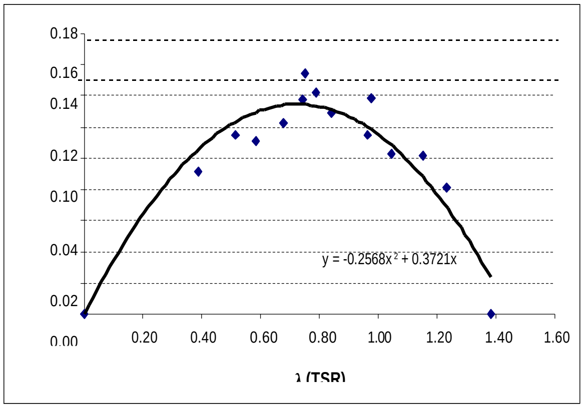

Figure 4. Coefficient of power and tip speed ratio of experiment with overlap ratio of 0.21

From result of experiment and also simulation above, the rotor can run with current speed 0.17m/s so can works in low speed current water. Considering the speed of tidal current in Sunda Strait are 0.4 -1 m/s, therefore the Savonius rotor can rotate due to the speed is higher than the simulation and experiment.

4.0 CONCLUSION

Although many researches have proposed the Savonius rotor for wind turbine applications, the work presented in this paper is one of the few dealing with marine current applications. The study provides a new concept of Vertical Axis Marine Current Turbine (VAMCT) especially for low current velocity 0.17 m/s. The simulation and experimental work have confirmed that the Savonius rotor can be worked in the low speed marine current. This is will be relevant with Sunda Strait condition that have current 0.4 – 1 m/s. The experiment also shows that the rotor provided torque 0.36 Nm with 11.97 RPM therefore can generated 0.45 Watt.

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