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Determine of Mechanical Torque of the Vertical Axis Tidal Turbine and Its Connection Systems

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Abstract: The issue of the global energy crisis requires researchers to seek renewable alternative energy. One technology that can be used as a solution in facing the global energy crisis is tidal energy. This tidal energy is absorbed using a water turbine, one of which is by using the Gorlove Vertical Axis Water Turbine. This study discusses the performance of the TASV Gorlove with NACA0018 blade profiles by adding wavy and vortex generators and is planned to be installed multiple. TASV Gorlove is designed to be built with three blades made of glass fiber reinforced polyester which is twisted at an angle of 120 degrees. Multiple installations are planned using a diamond-shaped joint, which allows for minimal heaving, pitching and yawing movements. Mechanical torque and turbine rotation speed are obtained based on water flow. The results of the experimental study of the maximum experimental torque value were 17.83 Nm, at 30.2 rpm rotation. Because the water flow is conditioned, there is no damage to the connection system. The performance of the turbine and diamond joint system is a new thing applied to multiple TASV Gorlove.

Keywords: Vertical Axis Water Turbine, Mechanical Torque, Gorlove Turbine, Alternative Energy, Experimental Study

1. Introduction

The increasingly limited availability of fossil-based energy sources, requires the discovery of alternative non-fossil-based energy sources. The growing costs and highly fluctuating prices of oil and natural gas, as well as their constantly diminishing supplies globally, have created the need for less expensive and sustainable alternative energy resources [1]. The use of non-renewable energy will cause weather changes that will cause bad effects, for example climate change in 2018 [2]. Many promising non-fossil energy sources exist in nature and can be used as alternative energy sources, one of which is water currents [3, 4]. In its application, the energy of water currents can be obtained from the tides of sea water and currents from irrigation channels/rivers. The VATT (Vertical Axis Tidal Turbine) Gorlove studied is a form of technology that can convert this energy. With the adaptive blade profile, the VATT Gorlove can efficiently absorb the kinetic energy contained in the water current into turbine rotation energy. The form of Gorlove's VATT under study is shown in Figure 1.

However, vertical axis water turbines (VAWT), installed in ocean and river currents can contribute to the sustainable and environmentally friendly exploitation of hydropower [5]. A more recent study focuses on increasing the efficiency through the study of the flow of fluid passing through the turbine. For this reason, the use of flexible blades on the vertical axis water turbine has also begun to be explored [6].

Figure 1. *Gorlove VAWT prototype.*

The fluid flow reaction force on the VATT Gorlove blade observed in a cross section (Figure 2) will always change according to its position. The value of these forces is determined based on the hydrodynamic coefficient C_d (drag) and C_l (lift) which will always change in function of the angle of attack. In addition, these blades also work with torque moments which tend to make the nose up or down on the blade. This study has been conducted with Numeca software, and is not examined in this paper.

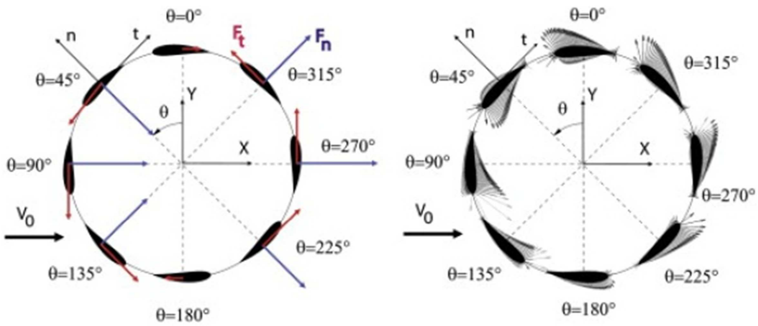

Figure 2. *Force and Pressure Distribution at hydrodynamic blade profiles [1].*

In its application, VATT Gorlove is projected to become a Tidal Energy Power Plant (TEPP) for archipelagic areas that are difficult to reach by the electricity supply network from PLN. Energi Pasang Surut, yang dimanfaatkan dari pasang surut yang bergerak, menyediakan sumber daya yang andal dan dapat diandalkan. Besarnya potensi Energi Pasang Surut tidak terbatas pada keandalannya tetapi juga ketersediaan sumber dayanya, dan jumlah penerima manfaat yang tinggi.

Thus, this potential can be utilized to develop remote island areas into tourist areas because of its tranquility. Dengan demikian potensi yang ada dapat dimanfaatkan untuk pengembangan kawasan pulau terpencil menjadi kawasal pariwisata yang tenang [9]. Another thing that can be projected by the use of VATT Gorlov in remote areas can improve the welfare of communities around rivers/irrigation by increasing community productivity.

The VATT Gorlov research was preceded by a request from Prof. Iskandar Alisyahbana (late), to try to design and manufacture it from composite materials in 2004. Since then, Polban has been involved in a growing global research chain with Alexander M. Gorlov's 1995 work producing turbines with 36% efficiency. Furthermore, the development is carried out by adding a wavy field and vortex generator to increase its absorption power. The problems that exist are the continuing efforts to increase efficiency, installation of turbine fields and installation in multiple verticals.

Figure 3. *Several potential areas that are predicted to be able to utilize this alternative energy generator, for example: Natuna Riau [8].*

The objective of this research is to find the optimal torque value generated from the VATT Gorlov with various installations that are predicted according to the actual conditions in the future. The estimated turbine torque and speed can be determined by Numeca software, and the hydrodynamic efficiency of the turbine can be determined as an indicator of VATT Gorlov's performance.

2. Research Methods

This research was conducted through the manufacturing process and experimental studies on the Jatiluhur irrigation flow. Measuring parameters and calculation techniques are carried out based on the Eq. (1) - Eq. (6).

1) Turbine angular velocity

$$\omega = \frac{2\pi n}{60}\ (rad/s) \quad (1)$$

2) Turbine forces

$$f = gW\ (N) \quad (2)$$

3) Turbine torque

$$T = FL\ \text{(Nm)} \quad (3)$$

4) Turbine power

$$P_t = \omega T \quad (4)$$

5) Water power

$$P_a = \frac{1}{2}\rho A V^3 \quad (5)$$

6) Turbine efficiency

$$\mu_T = \frac{P_t}{P_a} x\ 100\% \quad (6)$$

The implementation process of this research is done with some resistance, where the activity can be illustrated in a flow chart, as shown in Figure 5.

VATT Gorlove is manufactured using Glass Fiber Reinforced Polyester (GFRP) material, with a wet lamination process which is simpler but less precise. The initial process was carried out by making Gorlov's VATT models and molds. The wet lamination method has several advantages including, the process is relatively easy and much cheaper than using hot lamination. In this study also examined the feasibility of using GFRP materials, as well as the development of diamond connection system techniques which is a new thing applied to VATT Gorlov.

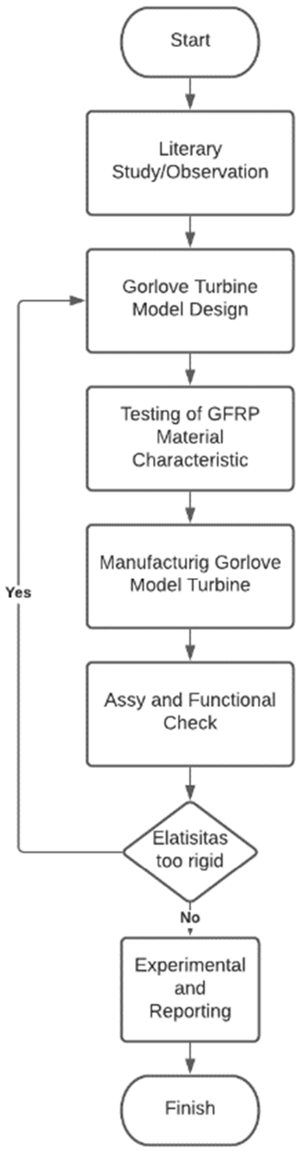

Figure 4. *Research flow chart.*

3. Results of Measurement and Discussion

The mechanical characteristics of the Gorlov VATT blade material was 63 MPa, which was obtained through an experimental study of tensile tests. The characteristics of the GFRP material test are shown in Figure 6. Determination of the deflection of the turbine is done by entering the moment from the previous experimental study of 5.1 Nm, then through computational simulation and experimental study to determine the displacement that occurs. The process and results of a computational study using Autodesk Inventor are shown in Figures 7 and 8.

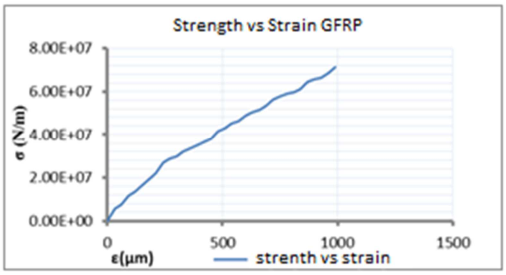

Figure 5. *GFRP Material Tension strength Graph.*

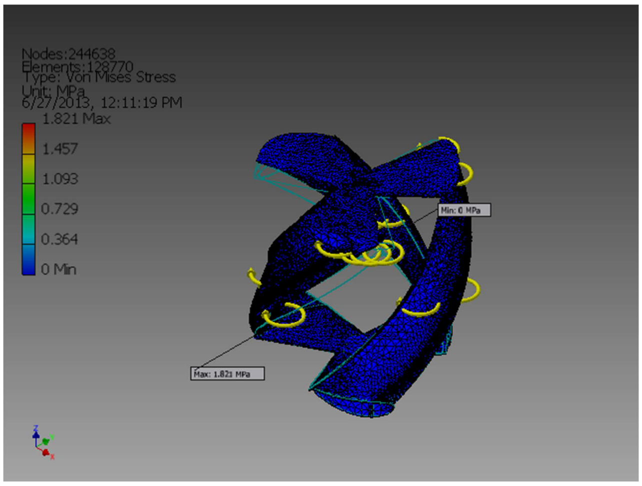

Figure 6. *Maximum Tensile Stress of VATT Gorlove.*

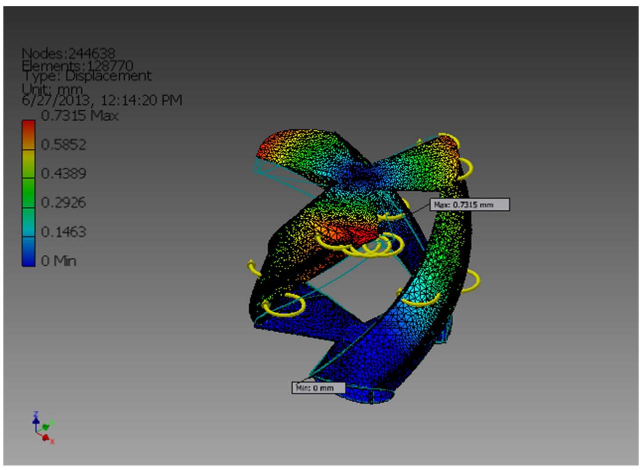

Figure 7. *Maximum deflection on the VATT Gorlove.*

In both figures, the simulation results show the maximum stress value that does not exceed the actual stress of the GFRP material. This indicates that the GFRP material is still very safe for use in the VATT Gorlov studied.

The Gorlove VATT test was carried out on the Jatiluhur dam irrigation channel in Purwakarta, West Java. With the water velocity that tends to be constant, this is an advantage for VATT Gorlov. The following is a picture of the Gorlov VATT test shown in Figure 8.

Figure 8. *VATT Gorlov assembly (left) and experimental (right).*

The maximum water velocity in the test is 1.5 m/s, and the maximum torque is 7,602 Nm, the maximum rotation is 100.2 rpm and the maximum power is 17.83 Watt. The graph of the rotation of the VATT Gorlov torque can be shown in Figure 9, yang cukup berbeda dengan hasil simulasi komputasionanl yang kecepatannya cenderung konstan [10].

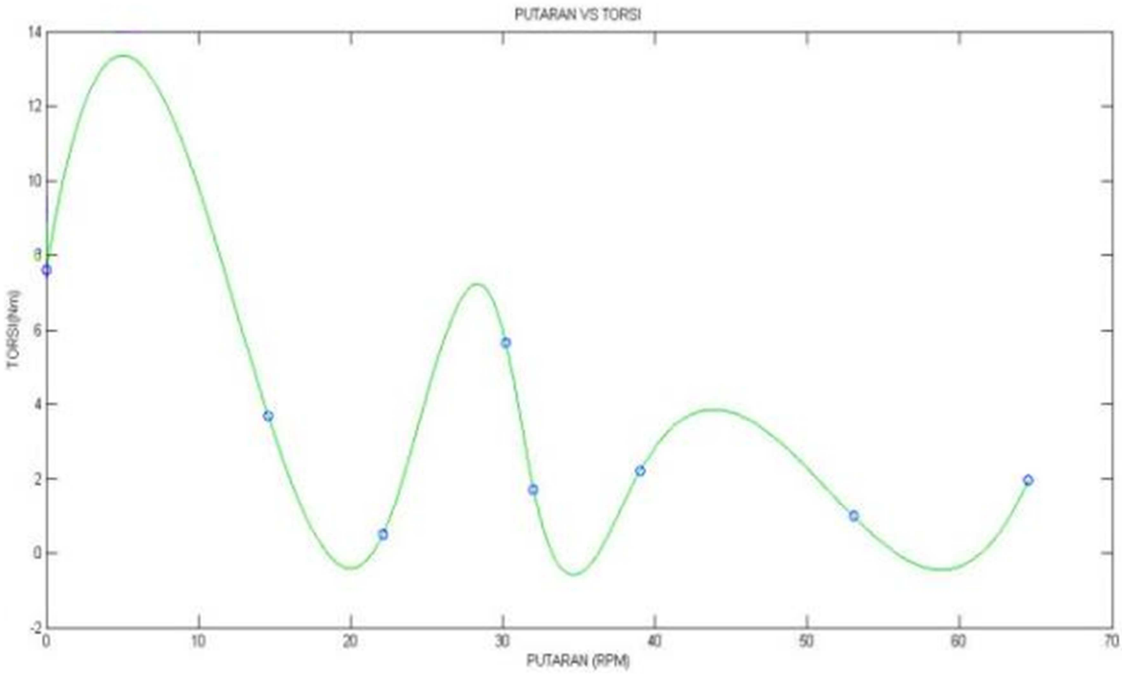

Figure 9. *Rotational velocity vs Torque curve.*

4. Conclusion

Based on the explanation from the experimental studies, VATT Gorlov produces an optimal torque value that is capable of producing a maximum torque value of 7,602 Nm, a maximum rotation of 100.2 rpm and a maximum power of 17.83 Watt. The alloy material structure of GFRP WR 200 2 layer, WR random 1 layer and 2-layer WR400 are safe for use on VATT Gorlov. From the actual results, the average maximum stress obtained is 63 MPa, while the maximum stress in the simulation results is 1.82 MPa. The diamond joint system on the VATT Gorlov is another supporting factor in the optimal performance of the VATT Gorlov.

Nomenklatur

P_t	Turbine Power (Watt)
ω	Angular velocity (rad/s)
ρ	Water density (kg/m^3)
A	Turbine cross section area (m^2)
V	Water velocity (m/s)
T	Torque (Nm)
μc	Turbine efficiency (%)
Pa	Daya air (watt)

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