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Experimental study of the effect of angle deflector horizontal axis water turbine (HAWT) drag type on power generation on water flow in the pipe.

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Abstract

One of the great potentials in generating electrical energy in Indonesia is by utilizing high rainfall and town buildings. This can be done by applying a horizontal axis water turbine (HAWT) in the building's pipes to generate energy. This study aims to determine the effect of the angle of the HAWT deflector on the ability to produce energy. Experimental studies of deflector angles on turbines were examined to determine optimal turbine performance. In this experimental study, testing was carried out using test equipment with a head height of 2 m. The deflector angle variations given were 20º, 30, 40º, 50º, 60º, and 70º. The data recorded are turbine rotation (rpm), voltage (volts), and electric current (amperes). Then calculation was made for the parameters to determine the power coefficient (Cp) and top speed ratio (TSR). The results of this study are provided from the most optimal turbine performance through the measurement of voltage data, output power, and power coefficient. The most optimal The resulting voltage is 9.90 [volt], the output power is 2.61 [watt] and the power coefficient is 3,16×10-2. Maximum TSR and CP at 40° deflector resulted in optimal performance. This is due to the 40° deflector trajectory to form a more precise fluid flow regarding the concave blade of the turbine to produce the greatest torque, thereby increasing the electrical power output.

Keywords:
Water Turbine, Depth to Width Ratio, HAWT,

1 Introduction

Electrical energy is a major need for humans. With the increasing global human population, the need for electrical energy is consequently increased proportionally [1]. Data on the population in Indonesia has reached more than 200 million people, implying a larger need for electrical energy resources. This creates an opportunity to develop new power plants. Indonesia's electrical energy needs are mostly supplied by fossil fuel power plants such as coal plants, gas plants, and diesel generators [2]. The utilization of environmentally friendly renewable power plants such as hydroelectric, geothermal, biomass, and solar thermal power plants is still on a small scale [3].

Water energy is one of the abundant renewable energy sources in Indonesia. Geographically, Indonesia is located on the equator which has a relatively high rainfall intensity. The current residential development is mostly directed at more multi-stories buildings which provide the potential for the utilization of wastewater. Both of these potentials can be used as a small-scale power plant (pico hydro) through the existing potential energy. This small capacity electricity can be used as an energy source in lighting lamps that use LED lamps. This lamp is an energy-saving lamp with low power of 3-15 Watts. With the combination of Pico hydropower plants and the use of LED lights, it is expected that the use of electrical energy from fossil materials in residential areas can be reduced.

A Pico hydropower plant is a small capacity power plant with a maximum power output of 5 kW. To increase the power output from the generator, the deflector can be modified. Hartadi et al [4] conducted research on the Savonius water turbine by adding a deflector plate to determine the changes in the power generated. Patel [5] conducted research by changing the function of a centrifugal pump into a turbine. This research was conducted by modifying the centrifugal pump to improve its performance. In the pipe installation, the short reducer and long reducer are varied with 2 installation variations. The long reducer at the turbine inlet produces a small pressure loss. In their study, Biswas [6] was able to increase the power input by 61.32% on the hydrokinetics turbine which is similar to the output generated from the Savonius wind turbine.

Chen [7] conducted research with simulations and experiments to determine the performance of the drag-type Vertical Axis Water Turbine (VAWT) on the flow in the pipe to produce electric power. The experiment was carried out for three generations covering the shape of the turbine, variations in the number of blades, and the shape of the blocking system, as well as comparing the solid-drag type turbine with the hollow-drag type turbine. From the simulation results, the comparison of the four blocking systems shows that the eye-shaped opening type blocking system produces the largest power output which produced a power output of 88.2 W with a water speed of 1.5 m/s and a pressure drop of less than 5 m.

In this experiment, we aim to increase the power output of the Horizontal Axis Water Turbine (HAWT) pico hydro power plant with the drag turbine type to be applied to a test apparatus. The head on the system is set to 2 meters. Variations in the deflector angle on the pipe will be tested on the Horizontal Axis Water Turbine (HAWT) to determine the effect on the electrical power generated by the generator.

2 Research Method

The research was conducted by using a modeling method and experimentally by using an apparatus test. Simulation using SolidWorks [8] was initially conducted and was followed by the experimental test. The Horizontal Axis Water Turbine (HAWT) drag type test was conducted using a turbine with several blades 8 [9] with a blade curvature angle of 70° [10]. Fig. 1 illustrates the turbine model and the variation of the deflector angle that has been planned. Fig. 2 shows six deflector tilt angles in this study, namely 20°, 30°, 40°, 50°, 60°, and 70°.

a. Turbine

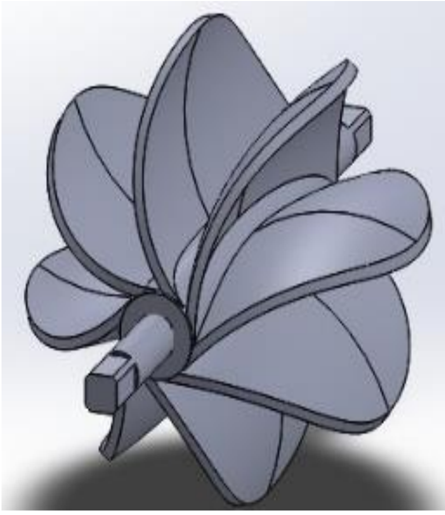


Fig. 1. An 8-blade turbine with a turbine curvature angle of 70°

b. Variation of Deflector Angle

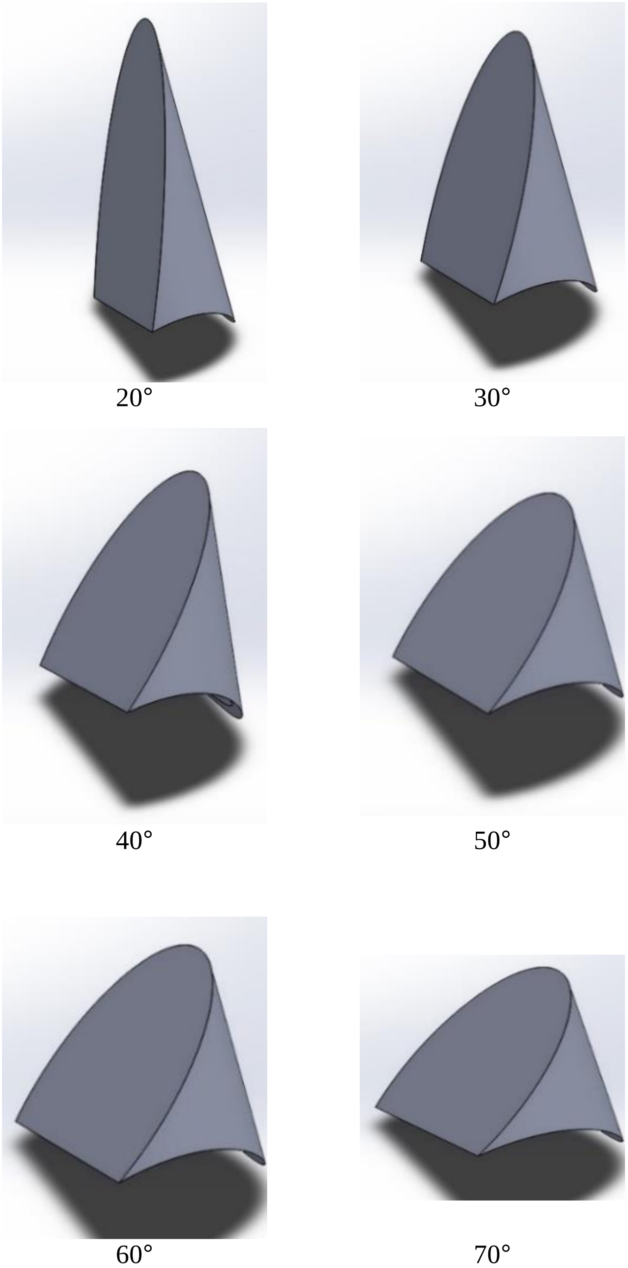


Fig. 2. Variation of deflector angle

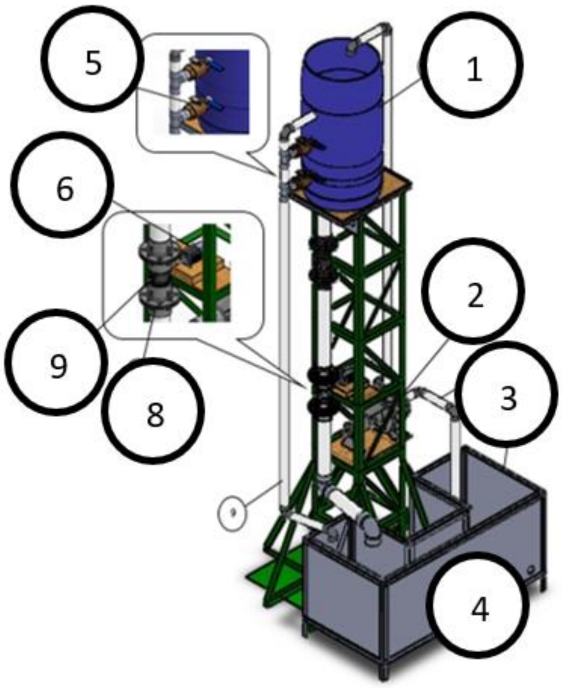
The simulation uses the SOLIDWORKS 2014 program with flow simulation facilities [11], [12]. Simulations were carried out with the following boundary conditions:

1. Simulation analysis was carried out for the flow in the pipe, with the acceleration relying on gravity through the negative Y axis with a value of??
2. The fluid used is water, with laminar and turbulent flow types.
3. The condition of the walls is adiabatic so that there is no heat transfer.
4. Initial conditions temperature 293.2 Kelvin, Pressure = 1 atm.
5. Inlet line: water discharge (Q) 0.019 m^3/s.
6. Outlet line: static pressure 1 atm.
7. The temperature of the water used is 293 Kelvin.
8. The mesh used is level 5

The simulation is carried out with the turbine at rest in the flow in the pipe. Before the flow of water enters the turbine, the water is first hit the deflector and then hit the turbine. The condition of surface roughness in the pipe is neglected.

c. Test equipment schematic

Testing of the Horizontal Axis Water Turbine (HAWT) drag type turbine was carried out using a test apparatus with a head of 2 meters. Data collection for testing was carried out at the fluid Mechanics Laboratory Sebelas Maret University. Fig.. 3 shows the setting of the test equipment to be used.



1. Tank
2. Centrifugal Pump
3. Incoming fluid pipe
4. Bottom tank
5. By-pass regulating valve
6. Alternator
7. Turbine housing
8. Flange
9. Pipa by-pass

Fig. 3. Apparatus test

Fig. 3 shows a schematic of the arrangement of the test equipment and its parts. From the top tank, the fluid flows into a series of turbines coupled to an alternator. Then the rotation and electric power are measured using a tachometer and digital multimeter. So that data obtained turbine rotation (rpm), voltage (volts), and electric current (amperes).

The data recorded are turbine rotation (rpm), voltage (volts), and electric current (amperes). Then, related parameters were calculated to determine the power coefficient (Cp) and tip speed ratio (TSR).

3 Results and Discussion

3.1 Simulation results

From the simulation, the values of torque, flow trajectories, and surface plots for each angle variation of the deflector were determined, then a turbine without a deflector is simulated to determine the effect of the deflector on the torque yield. By knowing the flow trajectories and surface plots, it is possible to analyze the distribution of pressure and flow on the rotor surface. Fig. 4 shows the torque value achieved for each torsion angle.

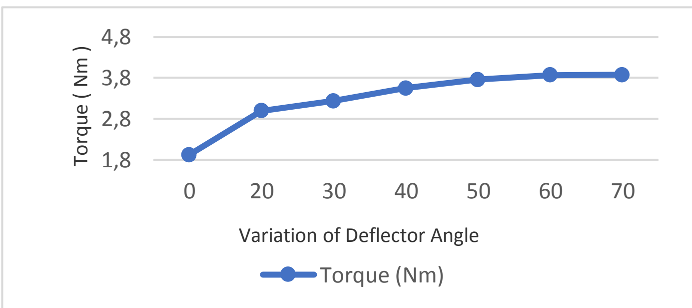
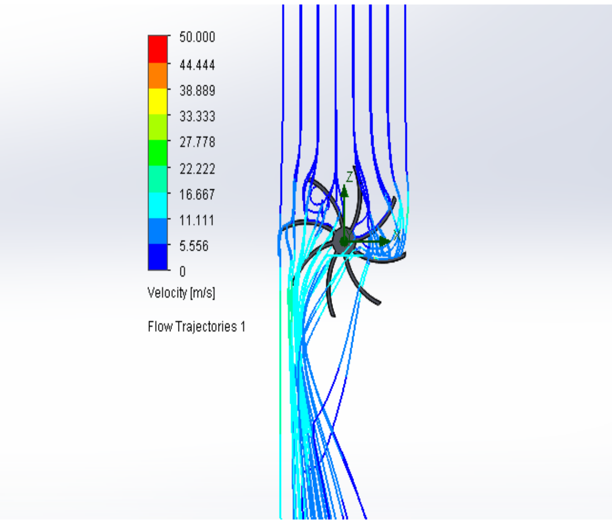


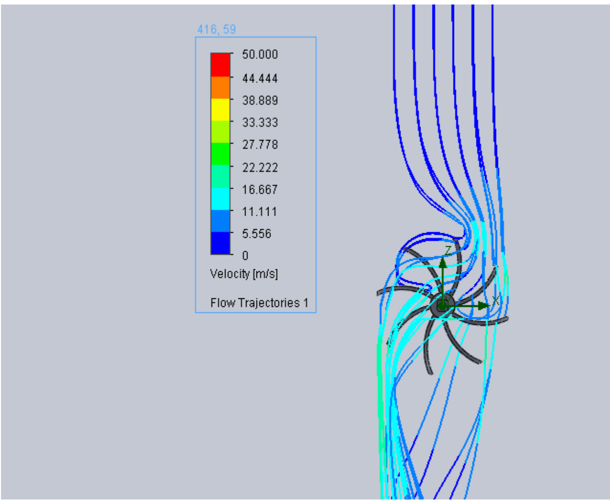
Fig. 4. Graph of torque on the angle variation of the deflector

Based on the above data, the turbine without deflector simulation produces the lowest torque of 1.92 Nm. In the simulation results, increasing the deflector angle variation from 20° to 70° tends to increase the torque values, with the maximum value was achieved by the maximum deflector angle of 70°, which is 3,874 [*Nm*]. This is because different phenomena occur as seen in the simulation of the resulting velocity and pressure contour (fig. 5).

The increase in the turbine torque from the turbine without deflector with a turbine fitted with a deflector is up to 84.2%. This proves that the deflector can reduce the back force on the water turbine. With the deflector plate, it can significantly increase the performance of the Savonius water turbine [13].



(a)

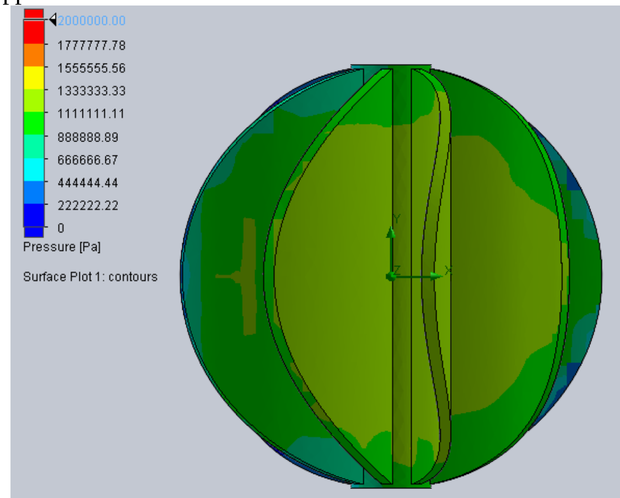


(b)

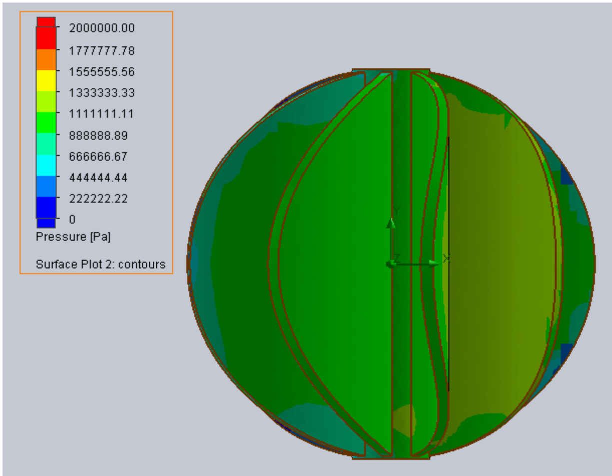
Fig. 5. Comparison of flow trajectories without a deflector (a) using a deflector (b).

The flow trajectories and the direction of the water that will hit the turbine are shown in Fire 5. The flow of water in the turbine with a deflector focused on passing through the deflector is directed to hit the concave blades of the turbine to produce a positive torque. Whereas in a turbine without a deflector, water flows directly into the turbine so that the convex and concave blades of the turbine are exposed to almost the same power flow. The color difference in the flow of water indicates the magnitude of the speed of the water.

In the simulation results of the surface plot without a deflector using a deflector (fig. 6), there is a large difference in pressure distribution on the convex blade. In a convex blade turbine, the blade pressure is greater than in a convex blade with a deflector. This is because in a turbine with a deflector the fluid flow is directed by the deflector towards the concave blades of the turbine to minimize the water hitting the convex blades of the turbine. Thus, this leads to a greater torque value on the turbine equipped with deflector.



(a)



(b)

Fig. 6. Comparison of surface plots without a deflector (a) using a deflector (b).

3.2 Experimental test results

Experimental test data which includes discharge (Q), turbine rotation (RPM), voltage (Volt), and electric current (amperes) are recorded and calculated. From the calculation, the data needed for analysis include the output electrical power, Tip Speed Ratio (TSR), and the power coefficient (C_P).

3.2.1 Analysis of the effect of the deflector angle on the velocity and power of fluid flow

Fig. 7 shows the increase of fluid flow velocity. In the experimental data, the results of the installation of the deflector angle show an increase in velocity with a small difference, this is caused by the condition of the surface of the deflector which is almost the same so that it affects the direction of fluid flow. The trend of water velocity in the deflector variation increases to a maximum point at a deflector angle of 40º then decreases to the lowest point at a deflector angle of 70º.

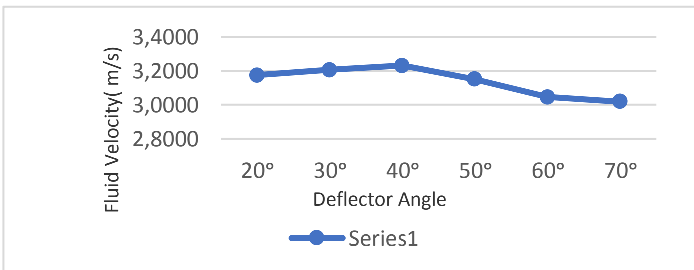


Fig. 7. Graph of fluid flow velocity (m/s) at various deflector angle

The amount of input power shown in Fig. 8 is generated by each deflector. The trend shown is an increase in input power from the deflector angle of 20º, 30º and the maximum input power at the deflector variation of 40º with 82.47 watts then decreases to a deflector angle of 70º with 77.09 watts. The turbine with a deflector of 70º has the lowest input power, this is because each variation of the deflector produces a different head. The magnitude of the different heads and discharges will affect the input power possessed by the fluid. While the input power will affect the performance coefficient produced by the turbine.

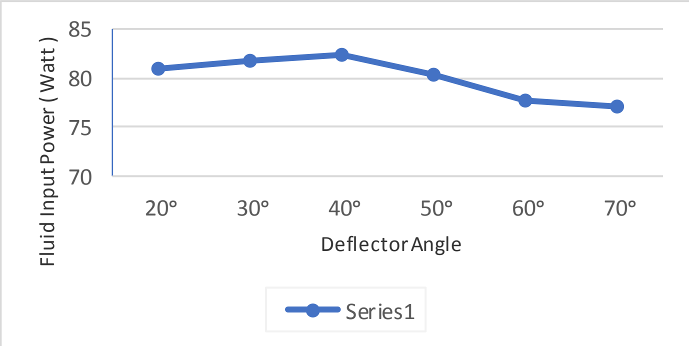


Fig. 8. The relationship between deflector angle variation and input power

3.2.2 Analysis of the Relationship Between Tip Speed Ratio and Power Coefficient (C_p)

Tip Speed Ratio (TSR) is one of the important parameters used to describe turbine performance. TSR is the ratio of the tangential velocity of the blade to the actual velocity of the fluid. Fig. 9. shows a graph of the relationship between the power coefficient and the tip speed ratio where the power coefficient is directly proportional to the increase in the tip speed ratio. This is by research that has been done [14].

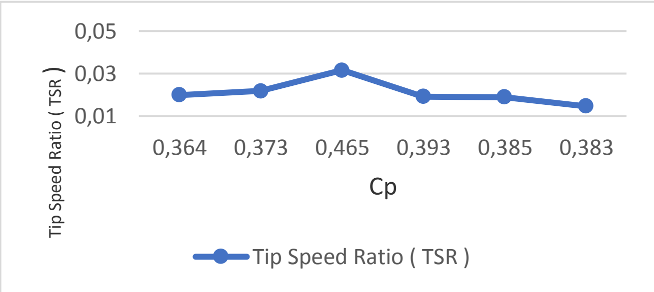


Fig. 9. Graph of relationship between Tip Speed Ratio (TSR) and C_P.

In the simulation study, there is an increase in turbine torque without a deflector with a turbine installed with a deflector up to 84.2%. This proves that the deflector can reduce the back force on the water turbine. Because the fluid flow that hits the convex turbine blades becomes smaller, it results in a smaller back force. The deflector plate can significantly increase the performance of the Savonius water turbine [13].

Maximum TSR and C_P at 40° deflector show the most optimal performance. This is due to the 40° deflector trajectory to form a more precise fluid flow regarding the concave blade of the turbine to produce the largest torque, thereby increasing the electrical power output.

4 Conclusion

Design From research conducted using Horizontal Axis Water Turbine (HWAT) with variations in deflector angles of 20º, 30º, 40º, 50º, 60º, and 70º, the following conclusions are obtained :

1. The addition of a deflector can reduce the turbine back force so that it can produce greater torque and power output.
2. The deflector angle of 40˚ has the best performance for application with a power output of 2.61 watts.
3. The flow rate affects the rotor power. The greater the flow rate used, the greater the power generated.

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References

[1] D. Amalia, H. Abdillah, and T. W. Hariyadi, “Analisa Perbandingan Daya Keluaran Panel Surya Tipe Monokristalin 50wp Yang Dirangakai Seri Dan Paralel Pada Instalasi Plts Off - Grid,” *J. Elektro dan Mesin Terap.*, vol. 8, no. 1, pp. 12–21, 2022, doi: https://doi.org/10.35143/elementer.v8i1.5187.

[2] W. F. Kurniawan, H. Abdillah, S. D. Ramdani, and Others, “Perancangan Prototype Penerangan Jalan Umum Menggunakan Solar Panel Off Grid 10 WP,” *J. Energi dan Teknol. Manufaktur*, vol. 5, no. 01, pp. 13–16, 2022.

[3] A. Alim, H. Abdillah, and S. D. Ramdani, “Analisis perbandingan daya keluaran modul solar cell 50 WP terhadap penambahan reflector cermin datar,” *Vocat. Educ. Natl. Semin. (VENS)*, vol. 1, no. 1, pp. 110–115, 2022.

[4] B. Hartadi and others, “PENGARUH KELENGKUNGAN DEFLEKTOR TURBIN SAVONIUS MODIFIKASI UNTUK TURBIN HIDROKINETIK,” *AL JAZARI J. Ilm. Tek. MESIN*, vol. 7, no. 1, 2022.

[5] S. R. Shah, S. V Jain, R. N. Patel, and V. J. Lakhera, “CFD for centrifugal pumps: a review of the state-of-the-art,” *Procedia Eng.*, vol. 51, pp. 715–720, 2013.

[6] N. K. Sarma, A. Biswas, and R. D. Misra, “Experimental and computational evaluation of Savonius hydrokinetic turbine for low velocity condition with comparison to Savonius wind turbine at the same input power,” *Energy Convers. Manag.*, vol. 83, pp. 88–98, 2014.

[7] J. Chen, H. X. Yang, C. P. Liu, C. H. Lau, and M. Lo, “A novel vertical axis water turbine for power generation from water pipelines,” *Energy*, vol. 54, pp. 184–193, 2013.

[8] F. Paundra, A. Nurdin, H. Abdillah, and P. Elmiawan, “Analysis of the Effect of Blade Thickness on Propeller Water Turbine Performance Using Computational Fluid Dynamic,” *VANOS J. Mech. Eng. Educ.*, vol. 7, no. 1, 2022.

[9] F. H. Napitupulu and F. Mauritz, “Uji Eksperimental Dan Analisis Pengaruh Variasi Kecepatan Dan Jumlah Sudu Terhadap Daya Dan Putaran Turbin Angin Vertikal Axis Savonius Dengan Menggunakan Sudu Pengarah,” *J. Din.*, vol. 2, no. 12, pp. 49–59, 2013.

[10] M. R. Ahmed, M. Faizal, and Y.-H. Lee, “Optimization of blade curvature and inter-rotor spacing of Savonius rotors for maximum wave energy extraction,” *Ocean Eng.*, vol. 65, pp. 32–38, 2013.

[11] S. Nurhaji and H. Abdillah, *Autocad basic 2 dimensi dan 3 dimensi*. Tangerang: Media Edukasi Indonesia, 2022.

[12] M. Munadi and H. Abdillah, “Pengaruh Resolusi 3D CAD STL Pada Kualitas Geometri dan Dimensi (G&D) Produk Pola Cor 3D Printer,” *Infotekmesin*, vol. 11, no. 2, pp. 130–136, Aug. 2020, doi: 10.35970/infotekmesin.v11i2.225.

[13] M. Halil, “Pengujian Kinerja Turbin Angin Savonius Sumbu Vertikal Overlap Dengan Deflektor Lengkung Ganda,” *Maj. Tek. Simes*, vol. 11, no. 1, pp. 23–30, 2018.

[14] G. Kailash, T. I. Eldho, and S. V Prabhu, “Performance study of modified Savonius water turbine with two deflector plates,” *Int. J. Rotating Mach.*, vol. 2012, 2012.