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Effect of variations in blade width on vertical shaft kinetic water turbine power

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Abstract

Various studies and observations have been carried out to produce a turbine design that suits the needs and the relatively low flow speed is a challenge that currently still requires further research. The aim of this research is to determine the effect of variations in the width of the bowl blade on the vertical shaft kinetic water turbine power. The research method used is an experimental method with an experimental design on a laboratory scale. Tests were carried out on three variations of blade width, from the results of the study it can be concluded that increasing the water flow rate, turbine rotation, and the ratio of tangential speed to the turbine blade width can increase the kinetic water turbine power. In this study, variations in blade width were 10 cm, 11 cm, and 12 cm. Increasing turbine blade sheets increased turbine power due to the additional mass of the flow hitting the turbine blades thereby affecting the kinetic water turbine power. Analysis of the water flow rate shows that the maximum turbine power occurs at a blade width of 12 cm and a discharge of 0.017 m3/second with a turbine power value of 25.455 Watt. Analysis of turbine rotation, Maximum turbine power occurs at a blade width of 12 cm and rotation of 80 rpm with a turbine power value of 23,864 Watts. Meanwhile, analysis of the tangential speed ratio shows that the maximum turbine power occurs at a blade width of 12 cm and at a tangential speed ratio of 0.5 rad/s2 with a turbine power value of 23,864 Watts.

Keywords: Blade width, power, kinetic turbine, vertical shaft

Introduction

Currently, the use of fossil fuels in the form of liquid or gas is the main source of energy to produce electricity(International Energy Agency, 2019). However, the use of fossil fuels contributes badly to the environment, such as global warming(Badrul Salleh, Kamaruddin and Mohamed-Kassim, 2019). Besides, energy demand continues to increase and causes energy scarcity(Indexed et al., 2018). The impact arising from the use of fossil energy has directed attention to a new era in finding new and renewable energy sources as efficient and sustainable sources of electricity production.(Fouz et al., 2019). The kinetic energy source of water is present as one of the most advanced renewable energy sources that can be developed in a simple form and has great potential in reducing energy crises and adverse impacts on the environment(Aghsaee and Markfort, 2018).

Hydrokinetic energy is an energy source available in the rivers and waterways with enough water velocity to move the kinetic turbine blades in the range of 0.5 m/s - 2.5 m/s(Guerra and Thomson, 2019),(Els and Junior, 2015). Hydrokinetic technology is based on the technique of converting the kinetic energy of water, such as rivers, into mechanical energy and becoming a promising future technology. There are fewer adverse effects of hydrokinetic technology on the environment than conventional turbines because it requires less building construction(Saini and Saini, 2020). This particular technology is unlike conventional power plants where the efficiency of the kinetic turbine does not depend on the Betz limit, which gives a theoretical maximum efficiency value of 59%(Niebuhr et al., 2019).

Kinetic turbines can be divided into two groups, namely vertical and horizontal shafts(Holanda et al., 2016). Some of the advantages of the vertical shaft kinetic turbine are that it does not require a water level, the density of the generated energy is greater, and the installation or maintenance of generators is easier(Aghsaee and Markfort, 2018),(Santos et al., 2019). However, kinetic turbines still have drawbacks, such as unstable rotation and low efficiency(Tjiu et al., 2015),(Giorgetti, Pellegrini and Zanforlin, 2015),(Rudy Soenoko, Setyarini and Gapsari, 2018). Therefore, many studies have been conducted to improve the performance of vertical shaft kinetic turbines, both experimentally and by numerical methods(Soenoko and Gapsari, 2018),(Patel, Eldho and Prabhu, 2018). In this study, testing was carried out on the vertical shaft kinetic turbine with three variations of blade width. Kinetic turbine testing aims to determine the effect of the variation of the blade width on the kinetic turbine power.

Literature Review

Definition of Kinetic Turbine

Kinetic turbine isa device that can produce mechanical energy in the form of shaft rotation with depending on the velocity of the water flow from the river and utilize the kinetic energy of water, ether kinetic energy of the water is then converted into mechanical energy in the turbine which is used to drive the generator so that it becomes electrical energy(Boedi et al., 2017).This turbine is very appropriate for use in flat areas that have river flows, especially rural areas(Yani, Mihdar and Erianto, 2017). Until now, there are two types of kinetic turbines known, namely kinetic turbines with a horizontal shaft and kinetic turbines with a shaft(R. Soenoko, Setyarini and Gapsari, 2018). The turbine used in this study is a kinetic turbine whose shaft is placed vertically.

Kinetic Turbine Working Principle

This kinetic tile utilizes the speed of water flow from the river, the water flowing past the blades experiences a change in momentum which can provide a pushing force on the blades so that the runner rotates. Here, the kinetic energy of the water changes into mechanical energy in the turbine which is used to drive the generator so that it becomes electrical energy. Where the energy change occurs in the turbine blades.In a vertical shaft kinetic turbine the water directly hits the blades on one half of the turbine wheel while the other half also gets hit but not as much as the first half so the turbine can still spin.(Yani, Mihdar and Erianto, 2017).

Kinetic Turbine Performance

The parameters that showed the kinetic turbine performance in this study were the power of the turbine. The power of the kinetic turbine could be determined by equations 1 to 3.(Yani, Septiani and Muliawan, 2020)

Turbine Power (Pt)

The power produced by kinetic turbines is water power that can be utilized or converted to mechanical energy on the shaft. Kinetic turbine power can be calculated by equation 1.(Yani, 2017)

$$P_t = T.\omega \qquad (1)$$

where :

P_t= Turbine power (Watts).
T = Torque (Nm).
ω= Angular velocity (Radian/s).

Torque can be calculated using equation 2.(Boedi et al., 2017)(Yani, 2017)

$$T = F.R \qquad (2)$$

where :

T = Torque (Nm).
F = Force, (N)
R = Pully radius, (m)

Angular velocity was attained by calculation using equation3.(Rudy Soenoko, Setyarini and Gapsari, 2018)

$$\omega = \frac{2.\pi.n}{60} \qquad (3)$$

where :

ω= Angular velocity (Radian/s).
n = Turbine rotation (rpm)

Research Method

This research was carried out using a laboratory scale experimental method using a vertical shaft kinetic turbine by testing variations in bowl blade width to determine the optimal kinetic turbine power.The parameters that indicate kinetic turbine power in this study can be determined using equations 1 to 3.Installation of a vertical shaft kinetic turbine research tool as shown in Figure 1.

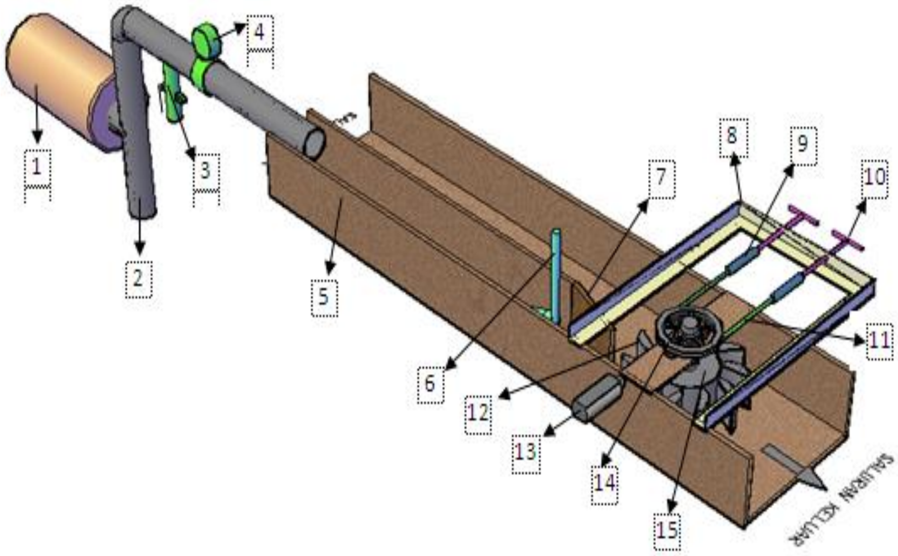


Figure 1. Kinetic turbine research installation

Notes of Figure 1:

1. Water pumps
2. Suction pipe
3. Water discharge valve (discharge tuner)
4. Flowmeters
5. Water channels
6. Flowatch
7. Water flow steering
8. Force load adjustment lever stand
9.SpringBalance
10. Force load adjustment lever
11. Ropes
12. Turbine blades
13. Tachometers
14. Pully
15. Turbine runners

Testing variations in the width of the blade bowl on the kinetic turbine as shown in the following figure:

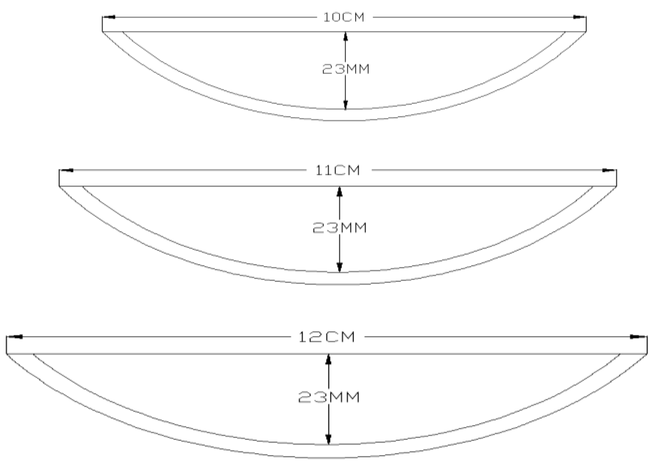


Figure 2. Variations in the width of the bowl blades studied

The variables used in this study consist of:

a. The independent variables are:
   1. Water discharge: 0.013, 0.014, 0.015, 0.016, and 0.017 m3/s
   2. Pully radius: 0.13 m
   3. The turbine rotation is conditioned to be constant at 100, 80, 60, 40, 20 and 0 rpm/s.
   4. The width of the bowl blades is 10 cm, 11 cm and 10 cm as shown in figure 2.

b. The dependent variable of this research is kinetic turbine power.

c. The Controlled Variables of this research are:
   1. The turbine rotation is determined to measure the amount of force (90 rpm, 70 rpm, 50 rpm, 30 rpm, and 10 rpm).
   2. Number of blades 8 pieces.
   3. The flow direction angle is conditioned to be constant at 250.
   4. The angular position of the turbine blade is 100 backwards

Research procedure

The procedure of this research are:

1. Prepare and install all research installations.
2. Install the measuring tools needed.
3. Check the condition of measuring instruments and other supporting tools.
4. Varying the width of the turbine blade according to what has been set is 10 cm, 11 cm and 12 cm.
5. Turn on the pump to distribute water.
6. Adjust the variation of water flow rate according to variations, namely 0.013, 0.014, 0.015, 0.016, and 0.017 m3/s.
7. Measure the rotation of the turbine shaft with a tachometer without load first. Next, measure the rotation of the turbine shaft with the load applied slowly by turning the force load adjustment lever until it meets the varied rotation, namely 100 rpm, 80 rpm, 60 rpm, 40 rpm, 20 rpm and 0 rpm.
8. Tests on a blade width of 10 cm were carried out three times to obtain accurate test data.
9. Repeat steps number 1 to 8 with varying blade widths of 11 cm and 12 cm.
10. Process and analyze the research data obtained to determine the relationship between the research variables that have been determined.
11. Draw conclusions from the results of the research conducted.

Results and Discussion

The relationship between flow rate and kinetic turbine power.

The relationship between discharge and kinetic turbine power for the three blade width variations is shown in Figure 3.

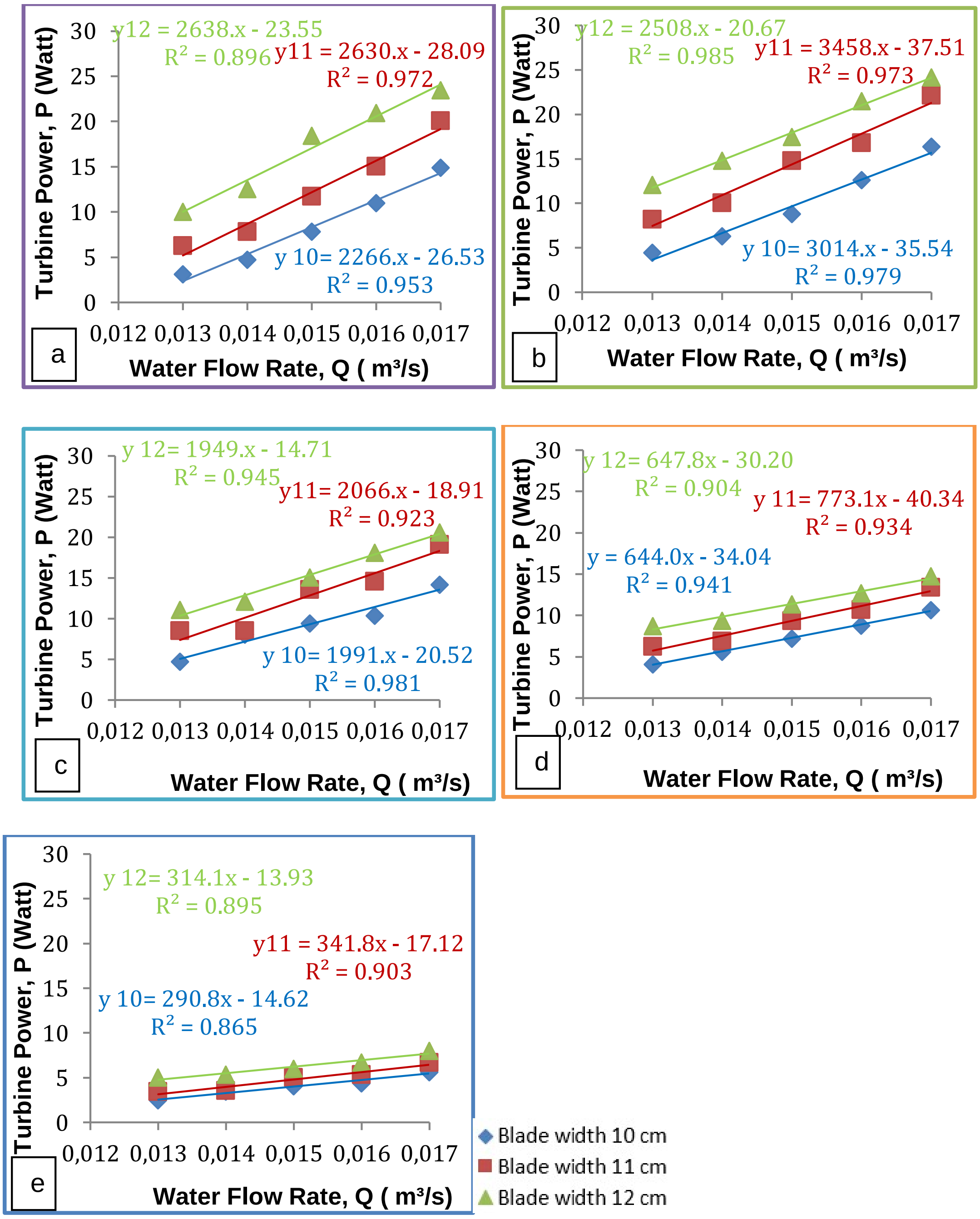


Figure 3. Relationship between water flow rate and turbine power at three variations in blade width.

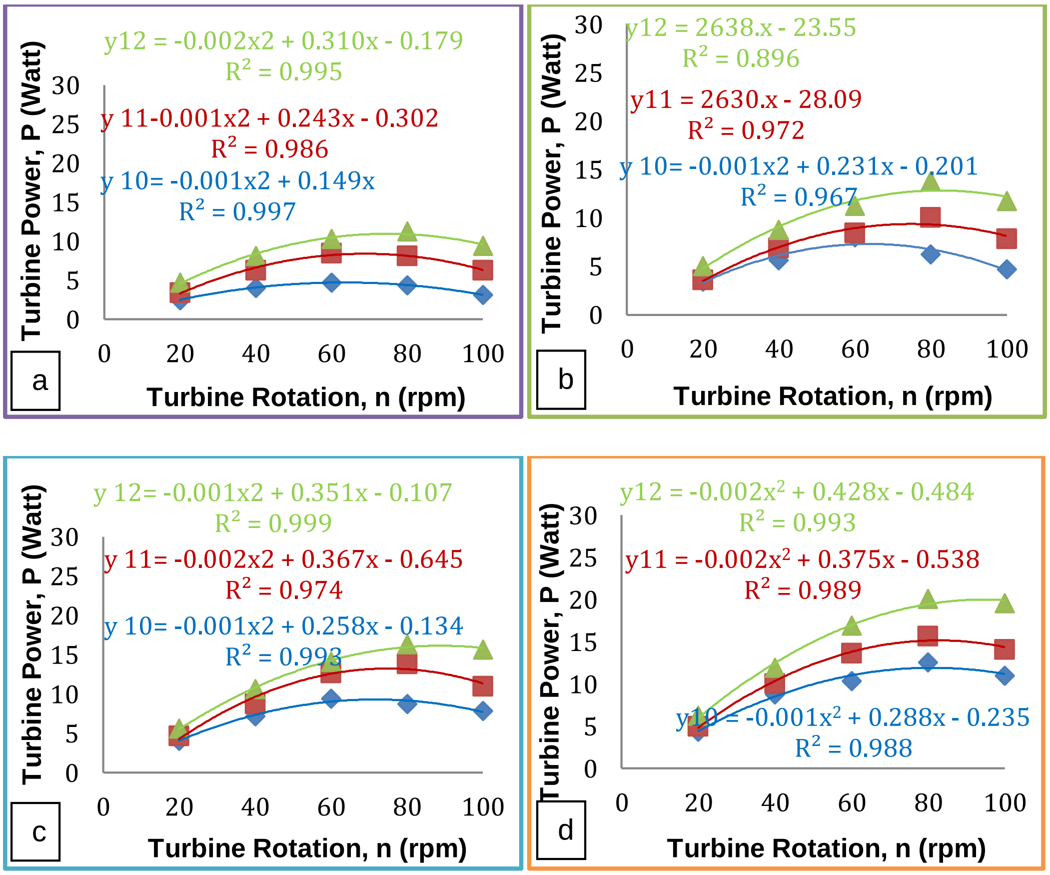
Figure 3 caption: (a). Rotation 100 rpm, (b). Rotation 80 rpm, (c). 60rpm rotation, (d). 40 rpm rotation, (e). 20rpm rotation.

In Figure 3 it can be seen that increasing the water discharge in the turbine channel can increase the kinetic turbine power. In this study, three variations of blade width were given, namely 10 cm, 11 cm, and 12 cm. The maximum kinetic turbine power occurs at a blade width of 12 cm, then decreases at a blade width of 11 cm and the lowest power occurs at a blade width of 10 cm. Turbine power is very dependent on the amount of torque and angular speed, the amount of torque is influenced by the rotation of the turbine, so that at high rotation it produces a large force and this force affects the torque. Meanwhile, the angular speed is influenced by the turbine rotation and the turbine rotation is very dependent on the mass of the flow hitting the turbine blades.

The water discharge is influenced by the water speed and the area of the turbine blades, while the area of the blades depends on the size of the blades. so that the water discharge affects the mass flow, turbine rotation and torque. The greater the turbine rotation and the water discharge provided, the more kinetic turbine power will increase. The blade width affects the kinetic turbine power, the wider the blade size, the kinetic turbine power increases due to the additional mass of the flow hitting the turbine blade so that the resulting tangential force increases and the tangential force affects the torque and kinetic turbine power. Maximum turbine power occurs at a blade width of 12 cm and rotation of 80 rpm and discharge0.017 m3/second with a value of 25.455 Watt.

The relationship between turbine rotation and kinetic turbine power.

The relationship between turbine rotation and kinetic turbine power at the three blade width variations is shown in Figure 4.



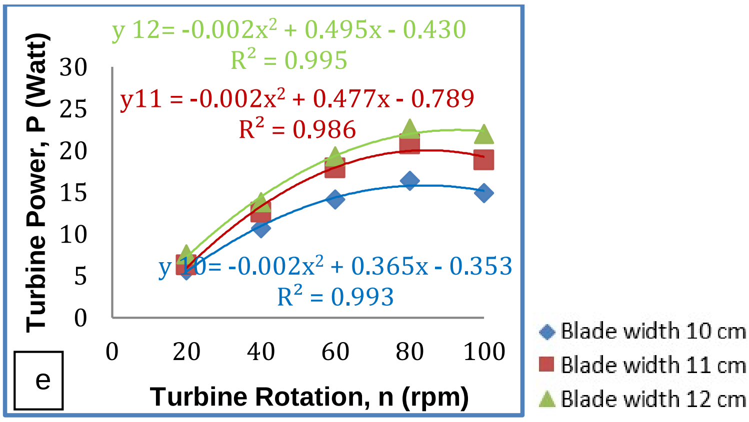


Figure 4. The relationship between turbine rotation and turbine power at the three blade width variations.

Caption for figure 4: (a). Water flow rate 0.013 m3/s, (b). Water flow rate 0.014 m3/s, (c). Water flow rate 0.015 m3/s, (d). Water flow rate 0.016 m3/s, (e). Water flow rate 0.017 m3/s.

In figure 4 it can be seen that increasing the turbine rotation and flow rate in the turbine channel will increase the turbine power. In this study, three variations of blade width were given, namely 10 cm, 11 cm and 12 cm. Based on Figure 4, the maximum turbine power occurs at a blade width of 12 cm, then decreases at a blade width of 11 cm and the lowest power occurs at a blade width of 10 cm. Turbine power is very dependent on the amount of torque and angular speed. The amount of torque is influenced by the rotation of the turbine, so that rotation with a large value will produce a large force and this force affects the torque. Meanwhile, the angular speed is influenced by the turbine rotation and the turbine rotation is very dependent on the mass of the flow hitting the turbine blade.

The water discharge is affected by the speed of the water and the area of the turbine blade, while the area of the blade depends on the size of the blade. so that the water discharge affects the mass flow, turbine rotation and torque. The greater the turbine rotation and the water discharge given will increase the turbine power. The width of the blades affects the power of the kinetic turbine, the wider the size of the blades, the more kinetic turbine power increases due to the additional flow mass that hits the turbine blades so that the resulting tangential force increases and this tangential force affects the torque and power of the kinetic turbine. Maximum turbine power occursat a water flow rate of 0.017 m3/s, at 80 rpm rotation and a blade width of 12 cm with a value of 23.864 Watt.

The relationship between the tangential speed ratio and the kinetic turbine power

The relationship between the tangential velocity ratio and kinetic turbine power at the three blade width variations as shown in Figure 5.

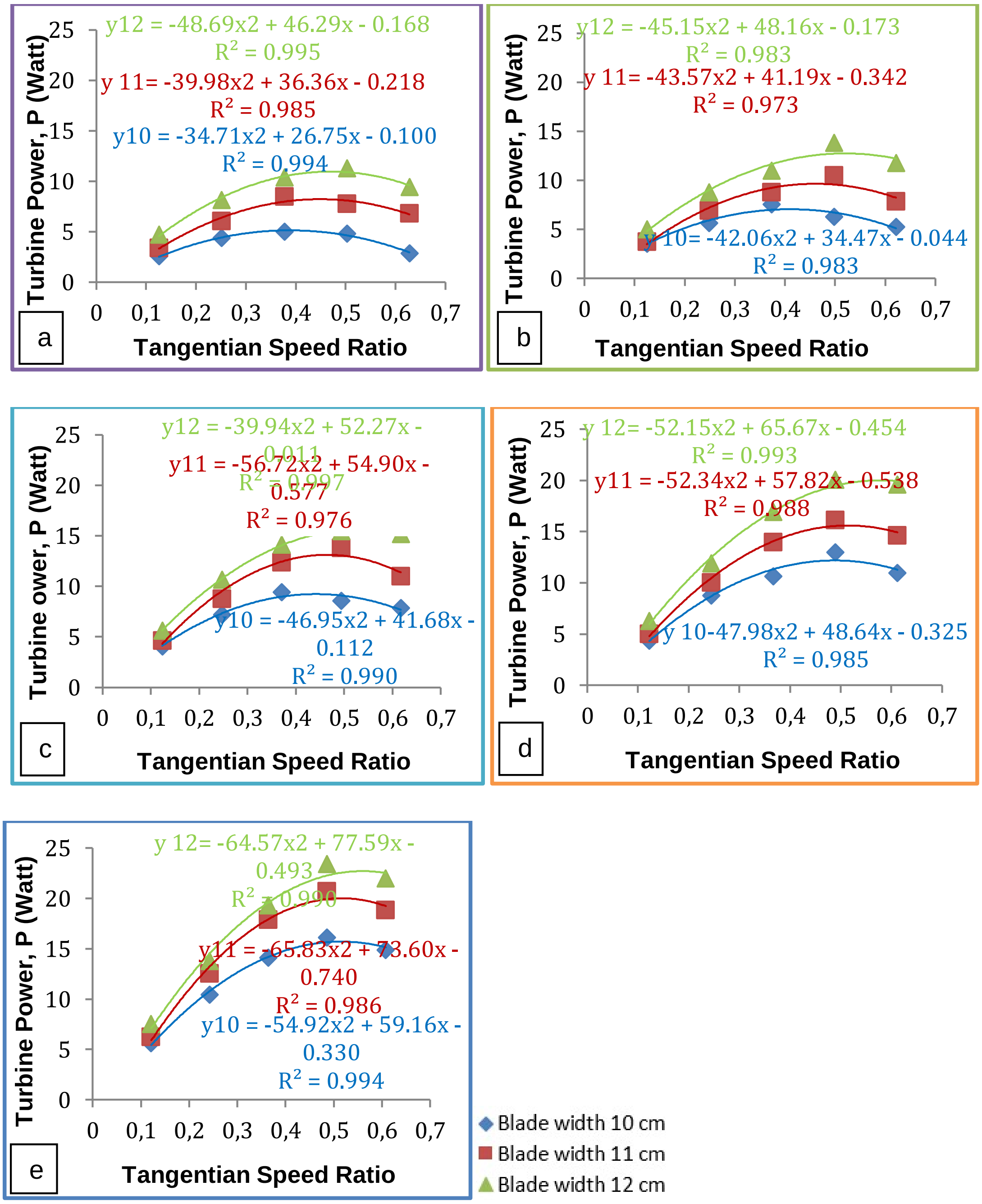


Figure 5. Relationship between tangential speed ratio and turbine power at three blade width variations.

Caption for figure 5: (a). Water flow rate 0.013 m3/s, (b). Water flow rate 0.014 m3/s, (c). Water flow rate 0.015 m3/s, (d). Water flow rate 0.016 m3/s, (e). Water flow rate 0.017 m3/s.

In Figure 5 it can be seen that increasing the rotation of the turbine runner will increase the power of the turbine. In this study, three variations of blade width were given, namely 10 cm, 11 cm, and 12 cm. Based on Figure 5, the maximum turbine power occurs at a blade width of 12 cm, then decreases at a blade width of 11 cm and the lowest power occurs at a blade width of 10 cm. Turbine power is very dependent on the amount of torque and angular speed.

The amount of torque is influenced by the rotation of the turbine, so that rotation with a large value will produce a large force and this force affects the torque. Meanwhile, the angular speed is influenced by the turbine rotation and the turbine rotation is very dependent on the mass of the flow hitting the turbine blades. The maximum turbine power occurs 0.017 m3/sec at a tangential velocity ratio of 0.

Conclusion

From the research results, it can be concluded that increasing the flow rate, turbine rotation, and the ratio of tangential speed to turbine blade width can increase kinetic turbine power. In this study, variations in blade width of 10 cm, 11 cm, and 12 cm, the addition of turbine blade sheets can increase turbine power due to the addition of flow mass that hits the turbine blade, thus affecting kinetic turbine power. Analysis of the flow rate, the maximum turbine power occurs at a blade width of 12 cm and a flow rate of 0.017 m3/second with a turbine power value of 25.455 Watts. Analysis of turbine rotation, maximum turbine power occurs at a blade width of 12 cm and rotation of 80 rpm with a turbine power value of 23,864 Watts. While the analysis on the tangential speed ratio,

References

Aghsaee, P. and Markfort, C.D. (2018) 'Effects of flow depth variations on the wake recovery behind a horizontal-axis hydrokinetic in-stream turbine', Renewable Energy, 125, pp. 620–629. Available at: https://doi.org/10.1016/j.renene.2018.02.137.

Ary, ES (2016) 'World Energy Resources 2016', 2007.

Badrul Salleh, M., Kamaruddin, NM and Mohamed-Kassim, Z. (2019) 'Savonius hydrokinetic turbines for a sustainable river-based energy extraction: A review of the technology and potential applications in Malaysia', Sustainable Energy Technologies and Assessments, 36(July), p. 100554. Available at: https://doi.org/10.1016/j.seta.2019.100554.

Boedi, SD et al. (2017) 'A vertical axis hinged blade kinetic turbine performance using a response surface methodology', Journal of Engineering Science and Technology, 12(8), pp. 2187–2201.

Els, RH Van and Junior, ACPB (2015) 'The Brazilian Experience with Hydrokinetic Turbines', Energy Procedia, 75, pp. 259–264. Available at: https://doi.org/10.1016/j.egypro.2015.07.328.

Fouz, DM et al. (2019) 'Hydrokinetic energy exploitation under combined river and tidal flow', Renewable Energy, 143, pp. 558–568. Available at: https://doi.org/10.1016/j.renene.2019.05.035.

Giorgetti, S., Pellegrini, G. and Zanforlin, S. (2015) '69th Conference of the Italian Thermal Machines Engineering Association , ATI 2014 CFD investigation on the aerodynamic interferences between medium-solidity Darrieus Vertical Axis Wind Turbines', 81, pp . 227–239. Available at: https://doi.org/10.1016/j.egypro.2015.12.089.

Guerra, M. and Thomson, J. (2019) 'Wake measurements from a hydrokinetic river turbine', Renewable Energy, 139, pp. 483–495. Available at: https://doi.org/10.1016/j.renene.2019.02.052.

Holanda, S. et al. (2016) 'Assessment of hydrokinetic energy resources downstream of hydropower plants', Renewable Energy [Preprint]. Available at: https://doi.org/10.1016/j.renene.2016.10.011.

Indexed, S. et al. (2018) 'effect Of Blade Number And Directional Plate Angle On Kinetic

Turbine Performances', 9(13), pp. 395–402.

International Energy Agency (2019) Electricity Information: Database Documentation.

Niebuhr, C. M. et al. (2019) 'A review of hydrokinetic turbines and enhancement techniques for canal installations: Technology, applicability and potential', Renewable and Sustainable Energy Reviews, 113(January), p. 109240. Available at: https://doi.org/10.1016/j.rser.2019.06.047.

Patel, V., Eldho, TI and Prabhu, S. V (2018) SC, Renewable Energy. Elsevier Ltd. Available at: https://doi.org/10.1016/j.renene.2018.12.074.

Saini, G. and Saini, RP (2020) 'A computational investigation to analyze the effects of different rotor parameters on hybrid hydrokinetic turbine performance', Ocean Engineering, 199(January), p. 107019. Available at: https://doi.org/10.1016/j.oceaneng.2020.107019.

Santos, IFS dos et al. (2019) 'Energy potential and economic analysis of hydrokinetic turbines implementation in rivers: An approach using numerical predictions (CFD) and experimental data', Renewable Energy, 143, pp. 648–662. Available at: https://doi.org/10.1016/j.renene.2019.05.018.

Soenoko, R. and Gapsari, F. (2018) 'Eight curved bladed kinetic water turbine performance', (October).

Soenoko, Rudy, Setyarini, PH and Gapsari, F. (2018) 'bowl Bladed Hydro Kinetic Turbine Performance', 13(20), pp. 8242–8250.

Soenoko, R., Setyarini, PH and Gapsari, F. (2018) 'Eight curved bladed kinetic water turbine performance', ARPN Journal of Engineering and Applied Sciences, 13(6), pp. 2138–2147.

Tjiu, W. et al. (2015) 'Darrieus vertical axis wind turbine for power generation I : Assessment of Darrieus VAWT configurations', 75, pp. 50–67. Available at: https://doi.org/10.1016/j.renene.2014.09.038.

Yani, A. (2017) 'Design of a Water Turbine Practicum Tool by Testing the Shape of the Blade on the Torque and Power of the Produced Turbine', Turbo: Journal of the Mechanical Engineering Study Program, 6(1). Available at: https://doi.org/10.24127/trb.v6i1.463.

Yani, A., Mihdar, M. and Erianto, R. (2017) 'the Effect Of Variation Of Blade Shape On Kinetic Water Turbine Performance (As an Alternative to Rural Area Power Generation)', Turbo: Journal of Mechanical Engineering Study Program, 5(1), pp. 1–6. Available at: https://doi.org/10.24127/trb.v5i1.113.

Yani, A., Septiani, M. and Muliawan, A. (2020) 'Analysis of the Effect of Various Flow Rates on Vertical Shaft Kinetic Turbine Performance', 4(11214), pp. 11214–11220.