# Study the Effect Diffuser Length and Degree to Horizontal Wind Turbine

Fatahul Arifin[1,2], R. D. Kusumanto[2,3], Yohandri Bow[2], Rusdianasari[2], Ahmad Taqwa[2], Afries Susandi[2], Yusuf Dewantoro Herlambang[4], Min Wen Wang[5] and Carlos R. Sitompul[3]

[1]*Department of Mechanical Engineering, Politeknik Negeri Sriwijaya, Jalan Srijaya Negara, Palembang, Indonesia*
[2]*Department of Renewable Energy Engineering, Politeknik Negeri Sriwijaya, Jalan Srijaya Negara, Palembang, Indonesia*
[3]*Department of Electrical, Politeknik Negeri Sriwijaya, Jalan Srijaya Negara, Palembang, Indonesia*
[4]*Department of Mechanical Engineering, Politeknik Negeri Semarang, Jl. Prof. Sudarto, Semarang, Indonesia*
[5]*Department of Mechanical Engineering, National Kaohsiung University Science and Technology, No. 415, Jiangong Rd., Kaohsiung, Taiwan*

Keywords: Diffuser, Wind Energy, Length, Angle, Power.

Abstract: Nowadays, Diffuser Augmented Wind Turbine (DAWT) has been used to improve wind turbine use in a low wind speed area by directing the wind speed. The technology is the pressure difference between inside and outside of DAWT, which is occurred. So, it increases the velocity of wind, and the power enhance as well. The software ANSYS was conducted to examine this study. The variation diffuser length (L) and angle were in range 0.5D-1.25D and the range 4$^o$-16$^o$. Experiments were also carried out under 3 conditions: wind turbine only, DAWT (L=0.5D) at 8$^o$ diffuser angle, and DAWT at 12$^o$ diffuser angle to observe voltage and electric current, power generated, and rotor rotation. The results show that installing a diffuser with a certain length and angle increases the power generated by 1.6-2.1 times higher than without a diffuser.



## 1 INTRODUCTION

The national and global energy problem is the rising cost of fossil energy; coal, gas, and oil. Naturally, energy prices will continue to increase, along with the accumulative scarcity of non-renewable energy sources and the rising demand for energy (Ploetz,et. al 2016).

Presently Wind turbine industry is becoming one alternative for energy production. In the financial aspect, the wind industry shows very intense progress, which is expected to participate in fossil fuel energy generation this decade.

On the topic of the importance of the turbine blade in its energy generation, lots of research has been developed to make the blade more efficient. Nicolette Arnalda Cencelli optimized a designed blade. In this research, some airfoils. They created the airfoil by using Xfoil software for different sections, then theresult showed new airfoils could increase the output power (Mohammadi, et. al 2016). The influence of the air density variation with altitude on the performance of a small horizontal axis wind turbine blade was studied by Pourajabian et al. (2014). Sharifi and Nobari studied in optimization of pitch angle along with wind turbine blades, based on a coding of aerodynamic. They obtained a coding of aerodynamic that could accurately predict the aerodynamics of horizontal axis wind turbines (Sharifi and Nobari. 2013). The type of vertical turbine strongly influenced by the swept area. The swept area affected drag and lift force, and then they applied dimensional engineering to obtain the optimal performance of the wind turbine (Yuliandi, et. al. 2021).

Diffuser Augmented Wind Turbine (DAWT) can be a favorable solution to solve those problems by adding a shroud to the turbine in increasing the wind turbine power output. The diffuser's working principle is to result in a pressure difference between the inside and outside the diffuser. This technology has developed in the early 1950s. These theoretical results were presented on small-scale wind turbines with shroud and increased power by 4% compared to lacking shroud in wind turbines (Putra, et. al 2018). The wind velocity profile around the diffuser, which



Arifin, F., Kusumanto, R., Bow, Y., Rusdianasari, ., Taqwa, A., Susandi, A., Herlambang, Y., Wang, M. and Sitompul, C.
Study the Effect Diffuser Length and Degree to Horizontal Wind Turbine.
DOI: 10.5220/0010951000003260
In *Proceedings of the 4th International Conference on Applied Science and Technology on Engineering Science (iCAST-ES 2021)*, pages 681-685
ISBN: 978-989-758-615-6; ISSN: 2975-8246

previously modified the diffuser in the form of additional inlet and flange curvature, had been studied by Putra, et. al. (2018).

Many researchers used the software to solve the design of the wind turbine. Susandi et al. studied Diffuser Parameters in the Performance of Horizontal Axis Wind Turbine using Computational Fluid Dynamics using Ansys software (Susandi et.al. 2021). Garmana et al. used the solid work software to investigate the combination of Savonius and Darrieus Turbine with differences in the Number of Savonius Turbine Blades (Germana et. al. 2021). Paranjape et al. (2020) studied the various designs, experiments, and CFD simulations of wind deflectors on Savonius wind turbine type using CFD software then concluded that installing a flat-plate deflector in the Savonius turbine can increase the power coefficient by 27%.

This study aims to analyze the performance of a horizontal axis wind turbine by applying variations in the length and angle of the diffuser.

# 2 METHODOLOGY

The design of the diffuser geometry is illustrated in Figure 1 (a). The design HAW turbine with and without a diffuser is shown in Figure 1 (b). The wind blows to the turbine entering through a diffuser with a smaller inlet cross-section than the outlet section.

Formula 1 shows the calculation of the amount of power generated in the diffuser based on density, area, and velocity (Bussel. (2007).

$$P = \frac{1}{2} A \rho v^3 Cp \quad (1)$$

where $P$ is power (W), $\rho$ is air density (1.225 kg/m3), $A$ is turbine swept area (m2), and $v$ is wind velocity (m/s)3, and $Cp$ is power coefficient. In this paper, Cp = 0.59 is the maximum value theoretically for the wind turbine, which is called *the Betz Limit* (Spera 2009).

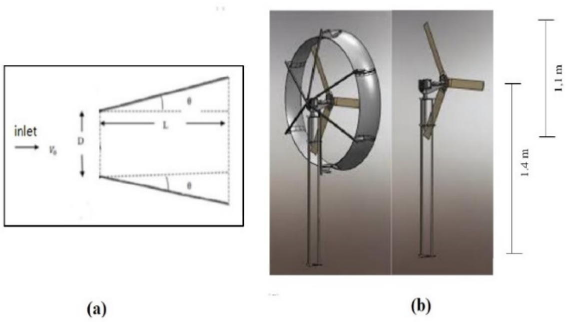


Figure 1: (a) Design Diffuser (b) Design of wind turbine with and without Diffuser.

The generator, measuring equipment, panel boxes, lights, sensors, and electrical installation is placed in the tower. The output of the wind generator is measured with voltage and current metering. Furthermore, the wind generator output is converted from Alternating Current (AC) to Direct Current (DC) through the Wind Charge Controller. The output of the Wind Charge Controller will supply the battery and LED lights. The voltage and current of the LED lamps are measured using a meter (power data logger). RPM on the wind generator is calculated using an RPM sensor that reads the rotation of the wind generator. The design of a horizontal axis wind turbine equipped with measuring tools can be seen in Figure 2.

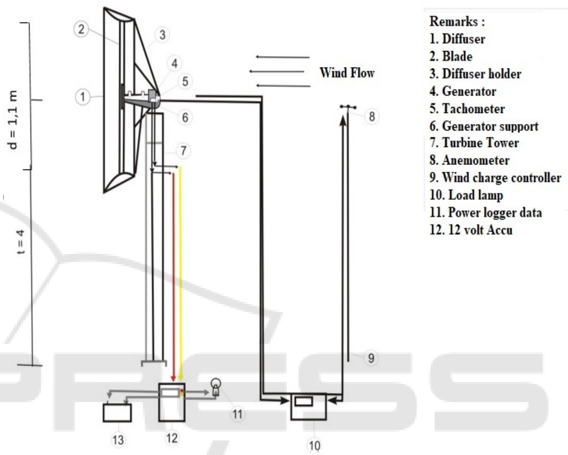


Figure 2: Structural Design of DHAW Turbine.

The study steps are reviewing the literature, running CFD simulation, designing and manufacturing wind turbines, finally collecting data. The flowchart of the study can be seen in Fig 3.

# 3 RESULT AND DISCUSSION

## 3.1 CFD Analysis Results

According to the result of running CFD, Ansys applied in this research with a magnitude velocity of 5 m/s. Then, the diffuser angles were changed 4$^o$, 8$^o$, 12$^o$, 16$^{o,}$ and the L = 0.5D to 2.5D while D = 1200 mm. The result is shown that the optimum diffuser angles are 8$^o$ to 16$^{o,}$ and the length is 0.25D to 1.25D (Susandi, et al 2021).

As shown in Figure 4, the wind enters the diffuser with the high velocity and then out the diffuser with low velocity. The best profile velocity contour can be obtained at a higher diffuser angle, and then the diffuser length gave an excellent performance from 0.5D until 1.25D.

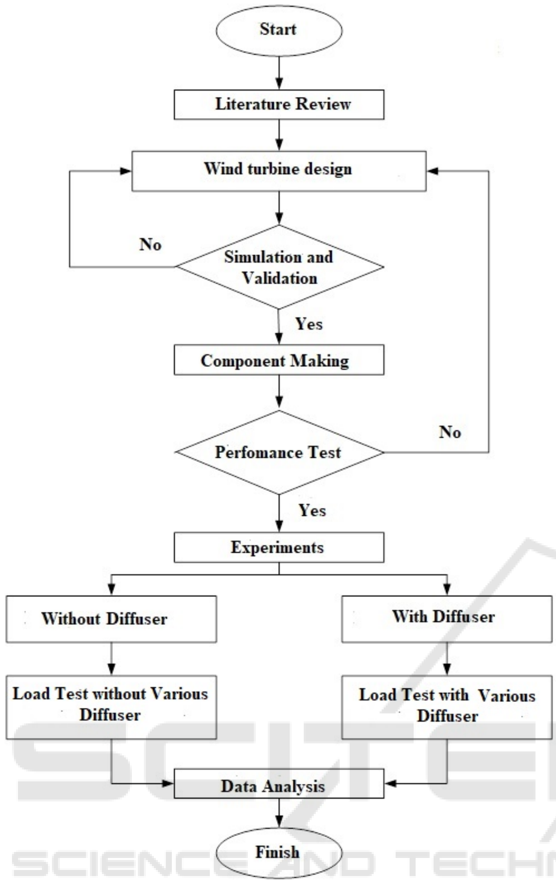


Figure 3. Research Flow chart.

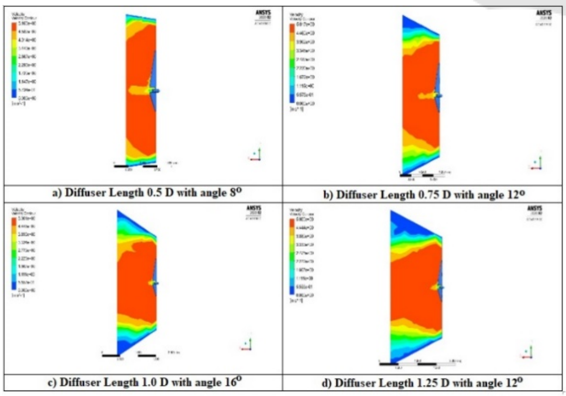


Figure 4: CFD of Ansys Fluent Simulation for Diffuser Length 0.5D to 1.25D angle 4° to 16°.

## 3.2 Comparison of the Power Generated in Theory and Experiment Results

Based on theories and experiments, it is possible to compare the power generated in the turbine without and with a diffuser. The values for calculating turbine power in theory and their comparison with turbine power experimentally can be seen in Figs. 5 – 7. It can be observed that by theory, there is an increase in power ($P_{Augmented}$) in the wind speed range of 1-5.5 m/s for each diffuser angle compared to the power of a horizontal axis wind turbine without a diffuser is 1.3-1.4 times. A diffuser with a length of L=0.5D and an angle of 8° can simulate an increase in turbine power of about 1.3 times.

Meanwhile, a diffuser with a length of L=0.5D and an angle of 12° can increase power up to 1.4 times. When compared to the power generated by theory and experiment in Figs. 5 -7 shows that the power generated by the approach is greater than the power induced experimentally. For example, at a wind speed of 3.5 m/s DAWT 12°, the Theory is 21.74 Watts, while the Experiment is 1.96 Watts.

The power generated in this theory is the available power from the wind turbine. The electrical power induced experimentally will be smaller than the available wind power. This is influenced by many factors, including the friction factor in the turbine, transmission efficiency, and generator efficiency, which causes the power generated by the system to be lower. It can be seen in Figures. 5 - 7 that the wind speed is directly proportional to the electrical power produced, meaning that the increase in wind speed and the electrical power generated are increasing.

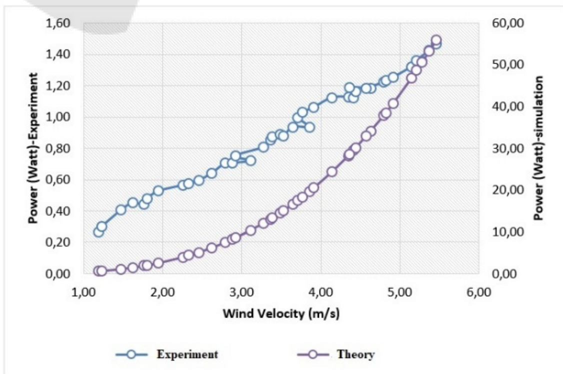


Figure 5: Power Generate by HAWT (Without Diffuser) Theory and Experiment.

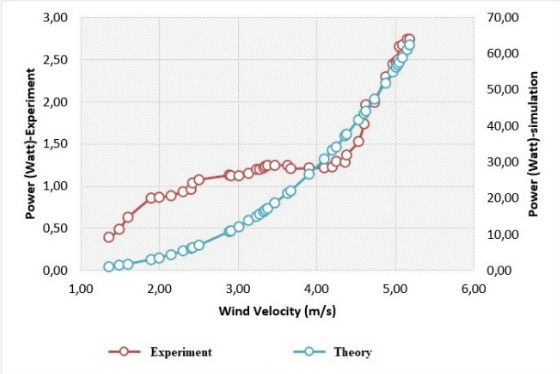


Figure 6: Power Generate by Wind Turbine with Diffuser 8°.

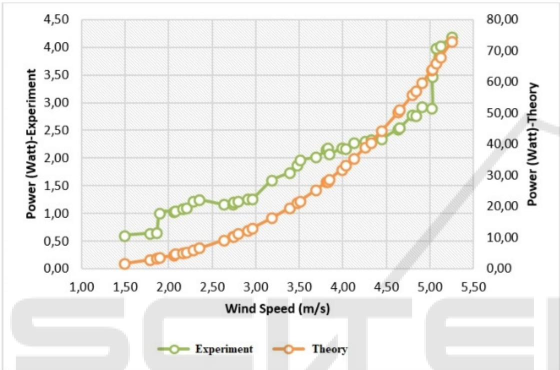


Figure 7: Power Generate by Wind Turbine with Diffuser 12°.

This is inseparable from the rotation. The increase in rotation of the turbine is in line with the increase in rotation of the generator. When the generator shaft starts to rotate, there will be a change in flux in the stator. Eventually, this flux change will produce a particular voltage and current whose value is directly proportional to the wind speed. This is also by the Betz Limit, which states that the maximum energy that can be converted is about 59% of the total kinetic energy of the wind and is commonly known as the power coefficient (*Cp*).

As can be seen in Table 1, the average enhancement of Turbine power theory is 1.3 for DAWT 8° and 1.4 for DWAT 12° higher than without diffuser, while in Table 2, the moderate enhancement of Turbine power experiment is 1.602 for DAWT 8° and 2.163 for DWAT 12° higher than without diffuser.

Table 1: The average enhancement of turbine power in theory.

| Wind Speed (m/s) | Turbine power without diffuser (Watt) | Turbine Power with DAWT 8° (Watt) | Turbine Power with DAWT 12° (Watt) |
|---|---|---|---|
| 1.0-2.5 | 2.011 | 4.042 | 4.334 |
| 2.6-3.5 | 10.894 | 14.739 | 14.561 |
| 3.6-4.5 | 23.375 | 32.829 | 33.479 |
| 4.6-5.5 | 43.950 | 55.139 | 60.834 |
| Average | 20.057 | 26.687 | 28.302 |
| $(P_{diffuser}/P_{tanpa\ diffuser})$ Average | | 1.3 | 1.4 |

Table 2: The average enhancement of turbine power in experiment.

| Wind Speed (m/s) | Turbine power without diffuser (Watt) | Turbine Power with DAWT 8° (Watt) | Turbine Power with DAWT 12° (Watt) |
|---|---|---|---|
| 1.0-2.5 | 0.460 | 0.816 | 0.961 |
| 2.6-3.5 | 0.783 | 1.188 | 1.442 |
| 3.6-4.5 | 1.069 | 1.335 | 2.201 |
| 4.6-5.5 | 1.300 | 2.449 | 3.210 |
| Average | 0.903 | 1.447 | 1.954 |
| $(P_{diffuser}/P_{tanpa\ diffuser})$ Average | | 1.602 | 2.163 |

# 4 CONCLUSIONS

The simulation results show that the length of the diffuser gives a better effect on the performance of the wind turbine, namely the length of the diffuser L is 0.25D to 1.25D, and the angle of the diffuser angle is 8° to 16°.

The experiments were carried out on 3 wind turbine conditions, namely on wind turbines only (without using a diffuser), a diffuser with a diffuser length of L=0.5D, and a diffuser angle of 8°, and a diffuser with a diffuser length of L=0.5D and a diffuser angle. 12°. Experimental data and graphs show the wind speed dramatically affects the voltage and electric current generated. If the wind speed is higher, voltage and electric current generated will be higher too. Be higher. The effect of installing a diffuser with a certain length and angle can increase the power generated by the wind turbine. The ratio of enhancement of the power of a diffuser wind turbine to a wind turbine without a diffuser is 1.6-2.1 times.

## ACKNOWLEDGEMENTS

This work was supported by Minister of Education, Culture, Research and Technology Republic Indonesia, Politeknik Negeri Sriwijaya. The financial support is acknowledged,

## REFERENCES

Bussel, G.J.W.V. (2007). The science of making more torque from wind: diffuser experiments and theory revisited, *J. Phys.: Conference Series 75*, pp. 1-12.

Garmana, A., Arifin, F., Rusdianasari, (2021). "CFD Analysis for Combination Savonius and Darrieus Turbine with Differences in the Number of Savonius Turbine Blades. *International Conference on Artificial Intelligence and Mechatronics Systems (AIMS)*, pp. 1-5, DOI: 10.1109/AIMS52415.2021.9466009.

Mohammadi, M., Mohammadi, A., Mohammadi, M., Minaei, H. N. (2016). Optimization of Small Scale Wind Turbine Blades for Low-Speed Conditions, *Vol. 4, No. 2,, Journal of Clean Energy Technologies,* 2016, DOI: 10.7763/JOCET.2016.V4.268.

Paranjape, A. D., Bajaj, A. S., Palanganda, S. T., Parikh, R., Nayak, R., Radhakrishnan, J., (2020). Computational Analysis of High Lift Generating Airfoils for Diffuser Augmented Wind Turbines, *Wind Energy Science-Discussions*, EAWE.

Ploetz, R., Rusdianasari, Eviliana. E. (2016). Renewable Energy: Advantages and Disadvantages, *Proceeding Forum in Research, Science, and Technology* (FIRST)

Pourrajabian, A., Mirzaei, M., Ebrahimi, R., Wood, D., (2014) "Effect of air density on the performance of a small wind turbine blade A case study in Iran," *Journal of Wind Engineering and Industrial Aerodynamics*, Vol. 126.

Putra, F. Q., Rifai, D., Suryopratomo, K., Budiarto, R., (2018). Multilevel Diffuser Augmented for Horizontal Axis Wind Turbine, *In proceeding of E3S Web of Conferences* (42), 01001, 2018.

Sharifi, A. and Nobari. M. R. H., (2013). Prediction of optimum section pitch angle distribution along wind turbine blades, *Energy Conversion and Management*, vol. 67.

Susandi, A., Arifin, F., Kusumanto, RD., (2021). Theory of Diffuser Parameters in the Performance of Horizontal Axis Wind Turbine using Computational Fluid Dynamics, Vol. 63, Issue 06, Journal *Technology Reports of Kansai University,*

Spera, D.A. (2009). Wind Turbine Technology-Fundamental Concepts of Wind Turbine Engineering, Second Edition. ASME Press, USA

Yuliandi, R. B., Rusdianasari, Dewi, T., (2018). Comparison of blade dimension design of a vertical wind turbine applied in low wind speed, *In proceeding of E3S Web of Conference EDP Science,* Vol. 68.