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Performance analysis of a three-blade spiral horizontal axis wind turbine with an aspect ratio of 0,116

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Abstract: The horizontal-axis wind turbine (TASH) is a wind energy technology that can generate electricity, but its performance still has to be improved. To determine how much an aspect ratio affects wind turbine performance, this study used a horizontal-axis wind turbine with three spiral blades and an aspect ratio of 0,116. The primary performance metrics of horizontal-axis wind turbines with three spiral blades and an aspect ratio of 0,116 are to be measured and examined in this work. Understanding how aspect ratio affects voltage (volts), current (amperes), torque (τ), turbine rotational speed (rpm), and in line with wind speed (ρw) in the process of generating electrical energy is the specific goal. A horizontal-axis wind turbine with three spiral blades and an aspect ratio of 0,116 will be constructed and tested in a controlled setting as part of this research's experimental methodology. The systematic measurement of essential performance characteristics, such as wind speed, torque, turbine rotational speed, voltage, and current, will provide a comprehensive understanding of the wind turbine's ability to generate electrical energy. The TASH experiment 3 spiral blades with an aspect ratio of 0,116 yielded the highest value when tested using a planetary gearbox at 24,23 rpm, 53,09 V of voltage, 1,25 A of electric current, and 30,94 Nm of torque at 5,0 m/s of wind speed. In the calculation of the power coefficient, torque coefficient, and tip speed ratio, the minimum value obtained in the test without a planetary gearbox was 0,0231 at wind speed 2,5 m/s, 0,2183 at wind speed 2,5 m/s, and 0,1059 at wind speed 2,5 m/s. The minimum value is obtained in the TASH test without a planetary gearbox with a rpm value of 105,89 rpm, Voltage 8,60V, Electric Current 0,05A, and Torque 2,85Nm at wind speed 2,5 m/s. A planetary gearbox with a power coefficient of 0,4713 at a wind speed of 4.5 m/s, a torque coefficient of 0,6813 at a wind speed of 4,0 m/s, and a tip speed ratio of 0,7525 at a wind speed of 5,0 m/s was used to test the system and determine the maximum value.

Keywords: Renewable energy; horizontal axis wind turbine; spiral blades

1. INTRODUCTION

The world's electrical grid has changed significantly in the modern era, particularly in terms of distribution and generation technology. These adjustments are intended to mitigate climate change and enhance energy security because wind energy has a high degree of flexibility. Indonesia possesses a significant potential for the usage of wind energy. The majority of Indonesia is made up of coastal regions with intense wind [1] [2]. A technological advancement that aids people in producing electricity from renewable energy sources is the wind turbine. Wind turbines are renewable energy power plants that generate electrical energy by harnessing the wind. Growing populations and industries result in higher energy requirements, particularly for electricity. Wind power is one of the many natural alternative energy sources that may be used to create electricity [3][4]. To build an ideal operating system for the development of horizontal axis wind turbines, numerous studies have been carried out (TASH). Using a variety of blade numbers, specifically 3, 4, 5, and 6, increases the power of the horizontal axis wind turbine, which is one of the innovations of the horizontal axis wind turbine (TASH). Utilizing the total of Arrow 3's 0,0358 watts at 445,63 rpm and Arrow 4's 0,0565 watts at 499,5 rpm, the producing power grows at a rate of 4 m/s. Bar 5 generates 0.0833 watts at a rotational speed of 538.60 rpm, whereas Bar

6 generates 0.0520 watts at a rotational speed of 467.83 rpm [5][6]. This study aims to investigate the variations of a horizontal axis wind turbine with three spiral blades and an aspect ratio of 0.116. The ratio of the front to rear blade distance is called the aspect ratio. The aspect ratio's impact on wind turbine performance has the potential to boost power [7]. Based on their axis of rotation, wind turbines are divided into two categories: vertical-axis wind turbines and horizontal-axis wind turbines [8]. The horizontal axis wind turbine (TASH) is the most often utilized form of wind turbine [9] It is powered by wind and has horizontally mounted blades. The wind strikes the blades from the front, rotates them, and powers the generator [10], a kind of wind turbine that rotates on an axis parallel to the direction of the wind, producing power. The ratio of the turbine blade's span length to its chord length, or the separation between its front and back blades, is known as the aspect ratio. Thus, the purpose of this study is to determine the values of the following parameters: torque, torque rotation speed, voltage, current, and tip speed ratio (λ). Additionally, the study will examine the effects of aspect ratio 0,116 on the efficiency of type 3 spiral bars horizontal-axis wind turbines (TASH): turbin coefficient power (Cp), torque (Ct), and tip speed ratio (λ).

2. METHOD

A literature review is conducted in the preliminary stages of research, which involves reading and examining references from books, journals, the internet, or earlier studies from domestic or foreign sources. To comprehend the theories or computations about the conducted research at this point [11]. The spiral blade horizontal axis wind turbine design, which was previously agreed upon, is implemented at the second stage of the design and design process [12]. The manufacturing of prototypes in compliance with the previously created design is the third stage [13] comprising the production of towers, yawing devices, and blades. The data retrieval diagram is described in Figure 1.

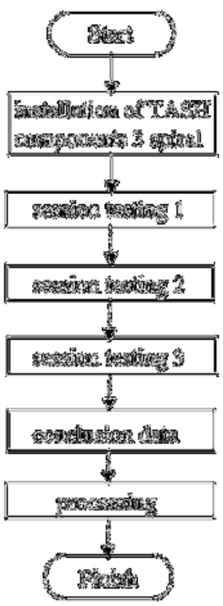

Figure 1. Data retrieval diagram

The field test for the horizontal axis wind turbine (TASH) was then carried out. Three sessions totaling two tests each session were-used to conduct the TASH field test. The morning session, the midday session, and the afternoon session of the third session. Tests to determine the quantity of Rpm, voltage, current, and torque as well as to validate TASH versus aspect ratio performance. The goal of data processing, which comes after gathering data from field testing, is to gather all data for review. The gearbox shaft that is attached to the generator is a source of data collecting [14]. The gearbox shaft rotation is then used to determine the rpm measurement [15]. Following that, data processing is done to produce the research's findings and conclusions. Data processing is done by doing computations using the data collected during the horizontal axis wind turbine field experiment.

3. RESULTS AND DISCUSSION

TASH Field test results data

The horizontal axis wind turbine data gathering process was conducted in an open area near North Jakarta's New Muara Beach to confirm the TASH's optimal operation in producing energy, with an aspect ratio of 0.116. This is the formula for the aspect ratio:

$$\text{Aspect Ratio}_{\text{blade}} = \frac{\text{Span}}{\text{Chord}} \quad (1)$$

Where:
Span: The total length of the turbine blade.
Chord: The average width of the turbine blade, measured from the leading edge to the trailing edge of the blade.

This test involved examining a wind turbine with three spiral blades on a horizontal axis with and without a planetary gearbox. The data from the planetary gearbox field testing of the horizontal axis wind turbine are shown below. The data from testing horizontal wind turbines with planetary gears is shown in Table 1.

Table 1. TASH testing data (planetary gearbox)

Testing time	Wind Speed (m/s)	TASH Rotation (RPM)	Voltage (V)	Current (A)	Torque (Nm)
Sesi 1	2,5	6,27	14,20	0,08	6,11
(09.00-10.00)	3,0	9,54	18,21	0,32	11,85
Sesi 2	3,5	13,04	25,98	0,60	16,97
(13.00-14.00)	4,0	16,74	35,81	0,86	22,77
Sesi 3	4,5	20,56	46,92	1,09	27,92
(16.00-17.00)	5,0	24,23	53,09	1,25	30,94

The lowest number, Revolutions per minute (RPM) 6,27 rpm, 14,20V, 0,08A, and torque of 6,11 Nm, is found at a wind speed of 2,5 m/s in the TASH 3 spiral blade experiment with an aspect ratio of 0,116. In contrast, the greatest value—24,23 revolutions per minute (RPM), 53,09V, 1,25A, and 30,94 Nm of torque—was recorded at a wind speed of 5,0 m/s. Consequently, it can be inferred from the data from the graph that the tester acquired using a planetary gearbox on a horizontal axis wind turbine with an aspect ratio of 0,116 that the more wind speed, the more power that is produced. Here are the average test values for horizontal axis wind turbines without a planetary gearbox. Table 2 displays the testing results for the horizontal axis wind turbine without a planetary gearbox.

Table 2. TASH testing data (without planetary gearbox)

Testing time	Wind Speed (m/s)	TASH Rotation (RPM)	Voltage (V)	Current (A)	Current (A)
Session 1	2,5	105,89	8,60	0,05	2,85
(09.00-10.00)	3,0	115,99	10,01	0,22	6,18
Session 2	3,5	129,13	14,86	0,41	8,99
(13.00-14.00)	4,0	141,25	20,01	0,57	11,93
Session 3 (16.00-	4,5	150,34	27,95	0,73	14,64
17.00)	5,0	163,41	30,43	0,84	15,73

The findings of the TASH 3 Blade experiment with an aspect ratio of 0,116 without a planetary gearbox reveal the lowest value at a wind speed of 2,5 m/s, with a (RPM) Revolutions per minute of 105,89 rpm, 8,60V, 0,05A, and a torque of 2,85 Nm. On the other hand, the maximum value was recorded at 5,0 m/s wind speed, 166,41 rpm (revolutions per minute), 30,43V, 0.84A, and 15,73 Nm torque. The data from the horizontal axis wind turbine with an aspect ratio of 0,116 without the planetary gearbox thus leads to the conclusion that the more wind speed, the more power generated.

Relationship between wind speed and rotor rotation (rpm)

The TASH test findings, both with and without planetary, indicate that the rotor rotation (rpm) is influenced by each wind speed value. The rotational speed of the rotor increases with increasing wind speed. The graph of rotor speed against wind speed is displayed in Figure 2.

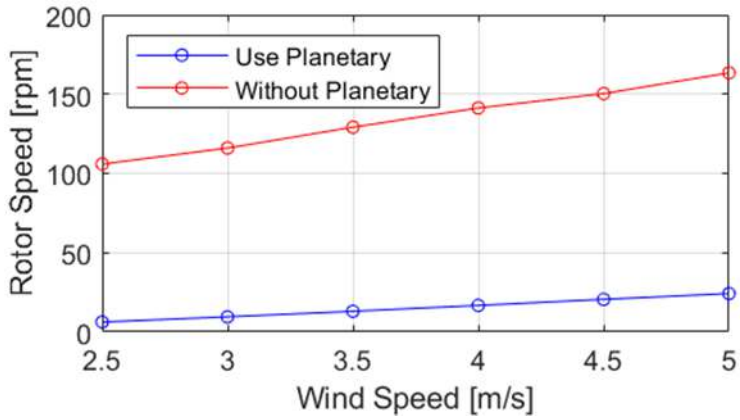

Figure 2. Effect of wind speed on rotor rotational speed

According to the graph above, the maximum rotor rotational speed (rpm) was reached at a wind speed of 5,0 m/s with a rotor rotation value of 24,23 rpm, and the lowest rpm value was at a wind speed of 2,5 m/s with a rotor rotation value of 6,27 rpm. These values were obtained during the TASH test using a planetary gearbox. While the lowest rotor rotation value was reached at a wind speed of 2.5 m/s with a rotor rotation value of 105,89 rpm, the greatest rotor rotational speed (rpm) was achieved at a wind speed of 5,0 m/s with a rotor rotation value of 163,41 rpm in the TASH test without a planetary gearbox.

Wind speed to voltage relationship

The test data from TASH with and without a planetary gearbox demonstrates how the stress value is impacted by each wind speed value. The resulting stress value increases with wind speed. The voltage versus wind speed curve is displayed in Figure 3.

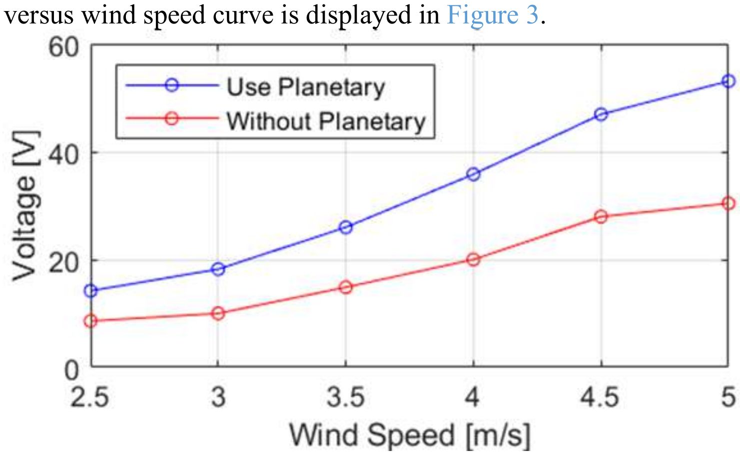

Figure 3. Effect of wind speed on voltage

The maximum voltage was reached in the TASH test with a planetary gearbox at a wind speed of 5,0 m/s and a voltage value of 53,09 V. The wind speed of 2,5 m/s with a voltage value of 14,20 V has the lowest voltage value. In contrast, the maximum voltage of 30,43V was attained in the TASH test without a planetary gearbox at a wind speed of 5,0 m/s. and the voltage value with the lowest wind speed, 2.5 m/s, is 8,60 V.

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Wind speed to current relationship

It is evident from the test data—both with and without a planetary gearbox—that the current value is influenced by each wind speed value. The amount of current produced increases with wind speed. The current strength graph versus wind speed is displayed in Figure 4.

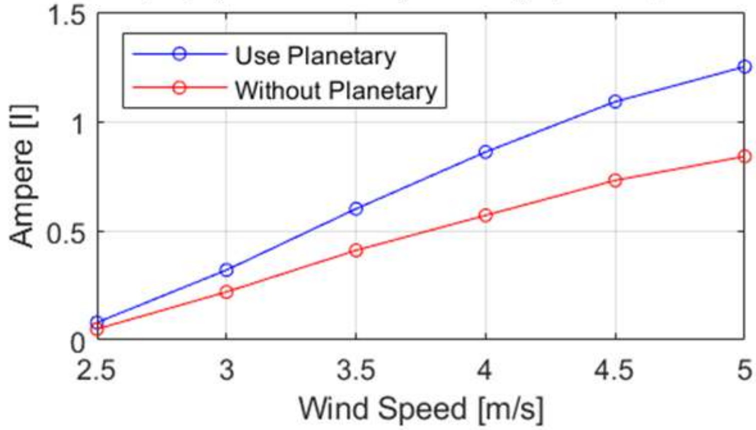

Figure 4. Effect of wind speed on current strength

The maximum current strength was reached in the TASH test using a planetary gearbox at a wind speed of 5,0 m/s and a current strength value of 1,25A. When the wind speed is 2.5 m/s and the strong current value is 0.08A, the lowest current strength is reached. The maximum current strength was attained in the TASH test without a planetary gearbox at a wind speed of 5,0 m/s and a strong current value of 0.84A. At a wind speed of 2.5 meters per second and a high current value of 0.05 amp, the lowest current strength is reached.

Wind speed to torque relationship

It is possible to concluded that each wind speed value influences the torque value based on the test results from TASH, both with and without a planetary gearbox. The more wind speed, the more torque produced. The torque vs. wind speed graph is displayed in Figure 5.

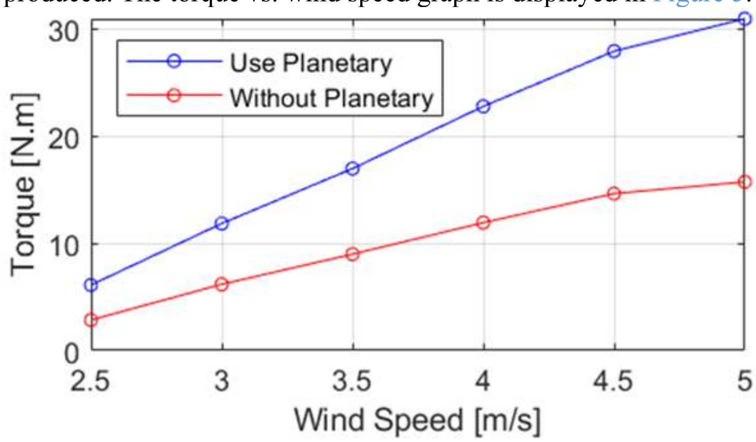

Figure 5. Effect of wind speed on torque

The torque value of 30,94 Nm was attained at a wind speed of 5,0 m/s in the TASH test utilizing a planetary gearbox, while 6,11 Nm was the lowest torque value at a wind speed of 2,5 m/s. The maximum torque of 15,73 Nm was obtained in the TASH test without a planetary gearbox, with a wind speed of 5,0 m/s. At a wind speed of 2.5 m/s, the lowest torque of 2,85 Nm was attained.

Data analysis results coefficient of power (Cp)

The experiment yielded higher theoretical and actual power outputs in proportion to wind speed. The real power graph of the experiment against wind speed is displayed in Figure 6.

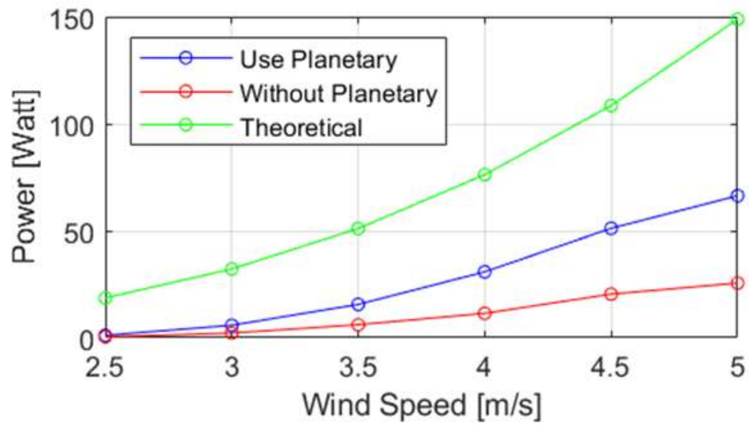

Figure 6. Wind speed versus experimental and theoretical power

Demonstrates that the TASH Experiment with a planetary gearbox has a higher actual power value than it would have without one. This is because planetary gearboxes can effectively alter power distribution and rotation ratio. This reduces TASH's rotating speed but results in a greater Experimental Actual value than when a planetary gearbox isn't used.

At a wind speed of 5,0 m/s, the highest experimental actual power on TASH utilizing a planetary gearbox is reached, with an experimental actual power value of 66,3625 W. At a wind speed of 2,5 m/s, the lowest experimental actual power is achieved, with an experimental actual power value of 1,1360 W. However, the experimental real power on TASH without a planetary gearbox achieves the lowest experimental actual power value of 0,4300W at 2,5 m/s wind speed and the greatest experimental actual power value of 25,5612 W at 5,0 m/s wind speed.

With a theoretical power value of 148,8414W at 5,0 m/s, the maximum theoretical power was attained, and with a theoretical power value of 18,6052W at 2,5 m/s, the lowest theoretical power was attained. The graph of power coefficient values against wind speed is displayed in Figure 7.

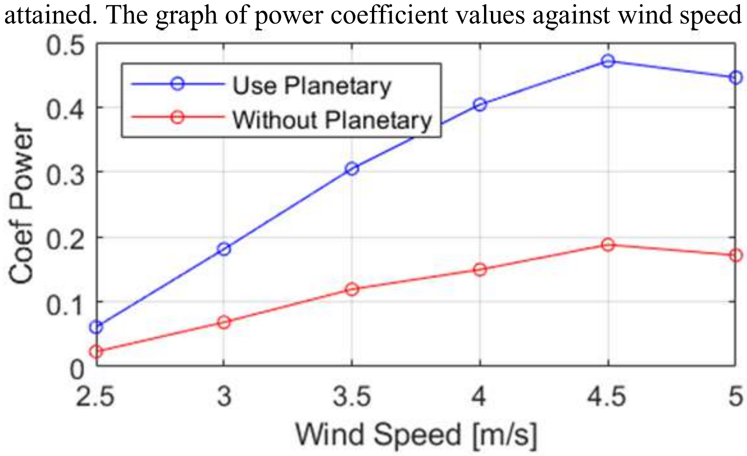

Figure 7. Graph of power coefficient value against wind speed

The power coefficient represents the relationship between the mechanical energy produced during the turbine's rotation and the mechanical energy derived from wind gusts that pass through the turbine. The graph demonstrates that TASH with a planetary gearbox has a higher power coefficient value than TASH without one.

With a planetary gearbox, wind turbines can reach their highest power coefficient values at 4,5 m/s with a power coefficient value of 0,4713 W, and their lowest at 2.5 m/s with a power coefficient value of 0,0611 W. In contrast, with a non-planetary gearbox, wind turbines can reach their highest power coefficient values at 4,5 m/s with a power coefficient value of 0,1880 W, and their lowest at 2.5 m/s with a power coefficient value of 0,0231 W.

Data analysis results of torque coefficient (Ct)

The predicted and experimental torque values are impacted by each wind speed value. The actual torque value of the experiment and the theoretical torque produced increase with wind speed. The actual torque numbers from the experiment and the theoretical torque produced increase with wind speed. The torque value graph against wind speed is displayed in Figure 8.

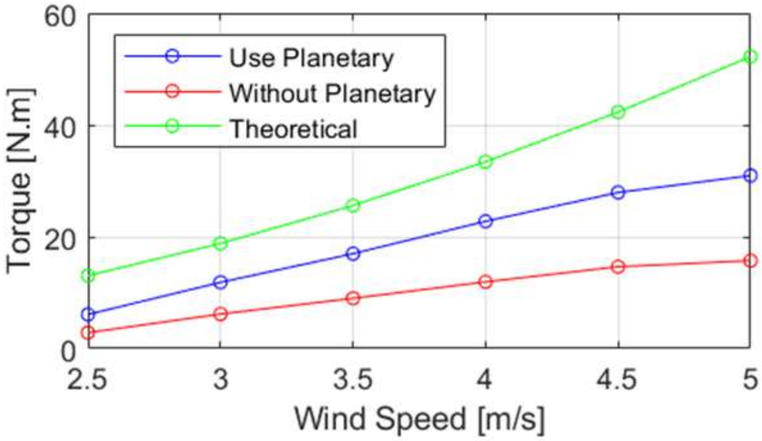

Figure 8. Graph of wind speed against torque value

The experimental real torque and theoretical torque values are impacted by each wind speed value. As can be shown, the experimental real torque value in the TASH test with a planetary gearbox is higher than in the test without one. This is because planetary gearboxes can effectively distribute power and alter the rotation ratio.

With a planetary gearbox, the testing revealed that the maximum experimental actual torque of 30,94 N.m. was obtained at a wind speed of 5,0 m/s, while the lowest experimental actual torque of 6,11 N.m. was obtained at a wind speed of 2,5 m/s. In the meantime, during testing without a planetary gearbox, the wind speed of 5,0 m/s produced the highest experimental actual torque, measuring 15,73 N. m, and the wind speed of 2,5 m/s produced the lowest experimental actual torque, measuring 2,85 N. m. Instance the highest theoretical torque was achieved at a wind speed of 5,0 m / s with a theoretical torque value of 52,2206 N.m and the lowest theoretical torque was achieved at a wind speed of 2,5 m/s with a theoretical torque value of 13,0552 N.m. Subsequently, the torque coefficient graph is computed and presented in Figure 9 as a graph against wind speed.

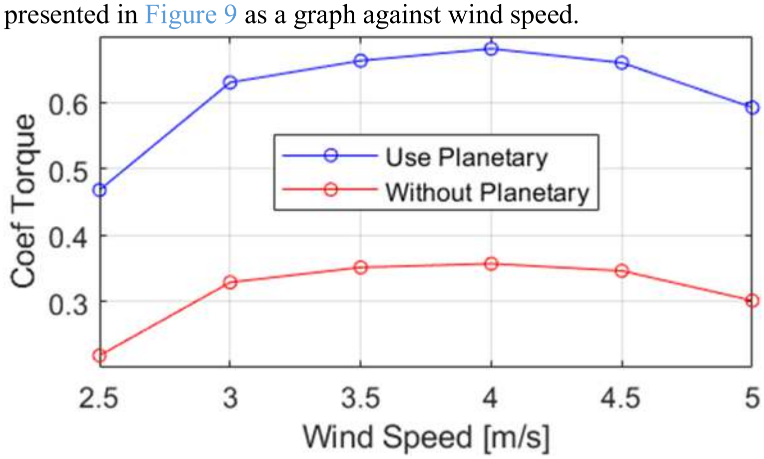

Figure 9. Graph of wind speed against torque coefficient

The torque coefficient value is independent of wind speed. The ratio of the theoretical torque to the torque value produced by the wind turbine spinning is known as the torque coefficient. Because planetary gearboxes can effectively distribute power and alter the rotation ratio, they have a higher torque coefficient resulting in the TASH test than they would have without them.

During the planetary gearbox test, the torque coefficient with the maximum value of 0,6813 N.m. was obtained at a wind speed of 4,0 m/s, while the torque coefficient with the lowest value of 0,4680 N.m. was obtained at a wind speed of 2,5 m/s. In contrast, the test conducted without a planetary gearbox yielded the highest torque coefficient, measuring 0.3570 N.m. at a wind speed of 4,0 m/s, and the lowest torque coefficient, measuring 0.2183 N.m. at a wind speed of 2,5 m/s.

Wind speed relationship to tip speed ratio (TSR)

It was discovered that the wind speed influences the Tip Speed Ratio value by adjusting the wind speed variable. The link between wind speed and the Tip Speed Ratio value is depicted in Figure 10.

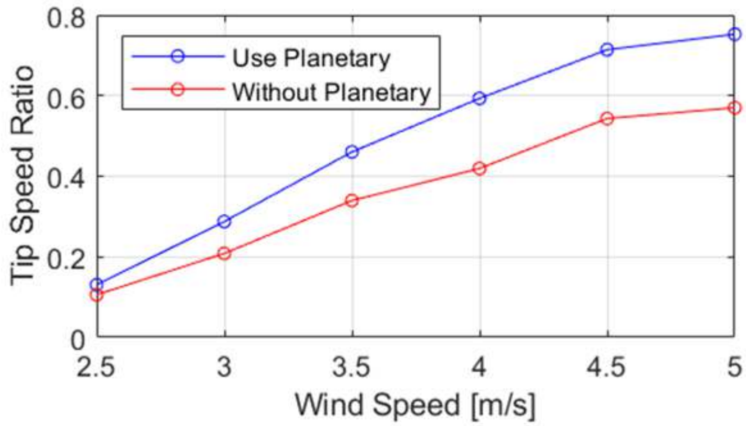

Figure 10. Graph of wind speed against tip speed ratio

Based on the wind speed against tip speed ratio graphical representation. The tip speed ratio's value is influenced by wind speed; the higher the wind speed, the higher the Tip Speed Ratio value that results. Due to the planetary gearbox's ability to effectively distribute power and alter the rotation ratio, the tip speed ratio in tests utilizing it is higher than in experiments that do not. In comparison to turbines without planetary gearboxes, those with planetary gearboxes can generate a greater tip-speed ratio value while also slowing down the turbine's rotational speed.

In planetary gearbox tests, the wind speed of 2,5 m/s of 0,1305 produced the lowest tip speed ratio (TSR) value, and the wind speed of 5,0 m/s of 0,7525 produced the highest value. In the test conducted without a planetary gearbox, the wind speed of 2,5 m/s of 0,1059 yielded the lowest tip speed ratio (TSR) value, and the wind speed of 5,0 m/s of 0,5701 yielded the greatest TSR value.

4. CONCLUSION

The 3-blade spiral's TASH test results, which have an aspect ratio of 0,116, indicate that the test without a planetary gearbox produced the lowest voltage, current, and torque, with values of 8,60V, 0,05A, and 2,85N.m at a wind speed of 2,5 m/s and a turbine rotation speed of 105,89 rpm. On the other hand, a planetary gearbox generated the maximum voltage, current, and torque throughout the test, measuring 53,09V, 1,25A, and 30,94 N.m. at a wind speed of 5,0 m/s and a turbine rotation speed of 24,23 rpm. The tests conducted without a planetary gearbox yielded the following results: a Power Coefficient of 0,0231 at a wind speed of 2,5 m/s, a Torque Coefficient of 0,2183 at a wind speed of 2,5 m/s, and a Tip Speed Ratio of 0,1059 at a wind speed of 2,5 m/s. These results are the result of the analysis of the Power Coefficient (Cp), Torque Coefficient (Ct), and minimum Tip Speed Ratio (TSR) produced. In the interim. In the tests using a planetary gearbox, the maximum values of the Power Coefficient (Cp), Torque Coefficient (Ct), and Tip Speed Ratio (TSR) were found to be 4,5 m/s for a Power Coefficient of 0,4713, 4,0 m/s for a Torque Coefficient of 0,6813, and 5,0 m/s for a Tip Speed Ratio of 0,7525.

REFERENCES

[1] D. H. Sinaga, R. R. O. Sasue, and H. D. Hutahaean, “Pemanfaatan Energi Terbarukan Dengan

Menerapkan Smart Grid Sebagai Jaringan Listrik Masa Depan," *J. Zetroem*, vol. 3, no. 1, pp. 11–17, 2021.

[2] H. Lathifah, . S., and . Y., "Analisis Potensi Pemanfaatan Energi Angin Sebagai Sumber Energi Listrik Di Indonesia," *J. Pendidikan, Sains Dan Teknol.*, vol. 2, no. 4, pp. 1005–1009, 2023, doi: 10.47233/jpst.v2i4.1330.

[3] D. L. Pristiandaru, "Cara Kerja Turbin Angin dan Komponennya." [Online]. Available: https://internasional.kompas.com/read/2022/02/04/123100670/cara-kerja-turbin-angin-dan-komponennya

[4] Ismail and T. Arrahman, "Perancangan Turbin Angin Sumbu Horizontal Tiga Sudu Dengan Kapasitas 3 MW," *Presisi*, vol. 6, no. 3, p. 113, 2017.

[5] N. Khusnawati, R. Wibowo, and M. Kabib, "Analisa Turbin Angin Sumbu Horizontal Tiga Sudu," *J. Crankshaft*, vol. 5, no. 2, pp. 35–42, 2022, doi: 10.24176/crankshaft.v5i2.7683.

[6] F. Aryanto, I. M. Mara, and M. Nuarsa, "Terhadap Unjuk Kerja Turbin Angin Poros Horizontal," *Din. Tek. Mesin*, vol. 3, no. 1, pp. 50–59, 2013.

[7] Y. Kurniawan, D. M. Kurniawati, D. Danardono, and D. P. Tjahjana, "Studi Eksperimental Pengaruh Aspek Rasio Terhadap Unjuk Kerja Turbin Angin Crossflow," *Pros. Snitt Poltekba*, vol. 3, no. 1, pp. 339–343, 2018, [Online]. Available: http://jurnal.poltekba.ac.id/index.php/prosiding/article/view/615/421

[8] A. Tummala, R. K. Velamati, D. K. Sinha, V. Indraja, and V. H. Krishna, "A review on small scale wind turbines," 2016. doi: 10.1016/j.rser.2015.12.027.

[9] A. Fadila and I. Zakaria, "Rancang Bangun Turbin Angin Tipe Darrieus Tiga Sudu Rangkap Tiga dengan Profil NACA 0006," *Eksergi*, vol. 15, no. 3, p. 102, 2020, doi: 10.32497/eksergi.v15i3.1785.

[10] H. W. Frasongko Budiyanto[1], Mustaqim[2], "GENERATOR TURBIN ANGIN PUTARAN RENDAH," *Engineering*, vol. 9, no. 2, 2014.

[11] S. Subagyo, M. Muflih, and A. Y. Atmojo, "Sistem Akuisisi Data Pengujian Kinerja Daya Turbin Angin Menggunakan Fasilitas Terowongan Angin," *J. Stand.*, vol. 17, no. 2, p. 129, 2016, doi: 10.31153/js.v17i2.312.

[12] S. W. Buana, P. Yunesti, G. B. Persada, and A. Muhyi, "Desain Turbin Angin Horisontal untuk Area Kecepatan Angin Rendah dengan Airfoil S826," *J. Sci. Appl. Technol.*, vol. 4, no. 2, p. 86, 2020, doi: 10.35472/jsat.v4i2.272.

[13] R. Nurhasanah, H. Maulana, B. Madi, Prayudi, A. Suardi, and V. Antono, "Rancang Bangun Turbin Angin Untuk Pembangkit Listrik Hybrid One Pole Energy," *J. Power Plant*, vol. 8, no. 2, pp. 82–89, 2020, [Online]. Available: https://doi.org/10.33322/powerplant.v8i2.1125

[14] M. Adam, P. Harahap, and M. R. Nasution, "Analisa Pengaruh Perubahan Kecepatan Angin Pada Pembangkit Listrik Tenaga Angin (PLTA) Terhadap Daya Yang Dihasilkan Generator Dc," *RELE (Rekayasa Elektr. dan Energi) J. Tek. Elektro*, vol. 2, no. 1, pp. 30–36, 2019, doi: 10.30596/rele.v2i1.3648.

[15] B. Augustiantyo, R. Setiawan, and O. Oleh, "Optimasi Desain Bilah Dengan Metode Linearisasi Chord Dan Twist Terhadap Performa Turbin Angin Sumbu Horizontal," *Media Mesin Maj. Tek. Mesin*, vol. 22, no. 2, pp. 97–110, 2021, doi: 10.23917/mesin.v22i2.14712.