Effect of Rotor Blades Number and Rotor Position on the Performance of a Diffuser Augmented Wind Turbine

Mohammed Mohsin Shkhair [1], Oday Kadhim Jaber [1, 2]
[1] Shatra Technical Institute, Southern Technical University, Iraq
[2] Mechanical Engineering Department, College of Engineering, University of Basrah, Iraq
Email: {mohammed79; odaykdham }@stu.edu.iq

Salih Meri Al Absi
Iraqi Cement State Company, Ministry of Industry and Minerals, Baghdad, Iraq
Email: salih.meri.ar@gmail.com

***Abstract*—A diffuser-driven wind turbine (DAWT) was used in this paper to increase the efficiency of small-sized horizontal axis wind turbines (HAWTs) by surrounding them with a suitable distributor. The study included two steps: first, knowing the effect of the number of blades inside the diffuser in three configurations (2-blades, 3-blades, and 4-blades), and secondly, showing the effect of the turbine position inside the diffuser in three cases based on the largest increase in wind speed in the diffuser. The numerical simulation investigation was carried out using 3D CFD ANSYS software by methods that rely on the *SST k-ω* turbulence model. The performance of the models was evaluated in terms of strength and aerodynamics coefficients, by calculating power coefficients C_P. The study showed that the turbine at the entrance to the diffuser gives the highest performance compared to other cases. Where the increase at the inlet the power coefficient of the turbine the diffuser is (22% and 14%) compared to its position in the middle of the diffuser and the end of the diffuser, respectively.**

***Index Terms*—horizontal axis wind turbine, blades number, turbine position, power coefficients C_P, 3D CFD ANSYS**

I. Introduction

To promote the development of renewable or green energy systems, sustainable energy systems based on renewable resources such as wind, sun, ocean, biomass, and geothermal energy are required. Alternative fuels made from renewable resources that are produced through chemical, thermal, and biological processes that reduce greenhouse gas emissions must also be developed [1]. Attributed development in the use of wind energy globally for a variety of reasons, including low cost, and availability of wind, especially in open areas. among the reasons for the development of power generation from wind, is the role of researchers in the development of systems used to extract energy from the air, which are called wind turbines, which were used in a wide range of applications in previous decades. As wind turbines are available in different shapes and sizes, they depend on many factors, produced power is the major factor that indicates the performance, which is related to wind speeds and turbine swept area [2].

The energy generated by wind turbines depends on the boundaries of the Betz scheme; where the optimum limit can produce only 59.3% of the incoming power [3], [4]. There are different types of wind turbines of different sizes, and part of these types is the horizontal axis wind turbines (HAWTs). HAWT, with a rotating diameter of fewer than 1.25 meters, is called a small turbine. Small sizes can be used in urban areas to produce energy [5], [6]. In order to better comprehend most aspects in studying DAWT, a review of some concepts and theoretical background on the experimental and numerical approaches are extremely essential.

To increase wind power to improve the performance of a HAWT by encasing the rotor in a diffuser, it is thus called a diffuser augmented wind turbine (DAWT) [7], DAWT can produce as much power as traditional wind turbines, and this is due to flow velocity increasing at rotor plane [8]. As well as, the use of a DAWT can reduce the size of the required generator and the weight of the entire turbine, leading to reduce the cost of production of power [9]. The diffuser shape model was changed with the help of an algorithm (SIMPLEX) to reach the optimal diffuser model. This method gained an average speed increase of 1.77 times the wind speed [10]. Power of wind turbines and a power factor increase of up to 14.5% were obtained exceeding the Betz limit [11].

Four different modified designs of blades have been tested in a wind tunnel. The results confirmed that coefficients of power for all modified blade designs were higher than standard design (baseline blade) at a low TSR range (0.5-3), but long wavelength blades work better [12]. The flange angle can be considered a minor parameter that can effect on diffuser's performance as mentioned in the simulation study conducted by A. M. El-zahaby et al. [13]

Manuscript received July 12, 2022; revised October 11, 2022.

doi: 10.18178/ijmerr.11.11.858-864

There are some investigations that have been devoted to the design and development of DAWT to further amplify the flow velocity and thus increase wind power. In this regard, the study looked into how to improve DAWT performance based on a variety of parameters, including the publisher's shape and design, As a result, focusing on the publisher's criteria is one of the most essential elements that influenced performance improvement [14], [8]. The geometry of the diffuser has been modified to raise the output torque by implementing a step in the outlet position of the diffuser. When the turbine was placed in the diffuser's inlet section, it was discovered that it had the highest power coefficient, and the implementation of this simple step boosted the coefficient [14] power by around 16 percent [8]. The wind turbine blades or diffuser structures can be manufactured from low-priced composite materials to reduce manufacturing costs. [15]. A model in which the flanged diffuser called wind lens turbine was used to improve the performance of the turbine, and the comparison showed an increase in power factor of 2-5 with the turbine without diffuser with the same parameters [16]

The experimental and numerical findings of the small DAWT show that the power gain of the DAWT - with flange up to 1.58 compared to that of the DAWT - without flange while it reached about 2.8 on the bare HAWT for the same turbine. Another study for a flanged diffuser with a curved interior is suitable for a micro-scale wind turbine. With the best geometry obtained for this diffuser, wind velocity increases up to 2.15 times over free stream velocity [8].

Through many types of research and studies in the field of diffuser augmented wind turbines, it is clear that the improvement of the efficiency of the HAWT depends heavily on the diffuser design. As a result, the focus of this study was to achieve the optimal HAWT design by the number and position of blades with a diffuser. Many experimental and simulation studies discussed in this part focused on achieving the highest increase in wind velocity at the use of the diffuser.

THE HAWT model was numerically tested within a suitable diffuser using the Ansys CFD. Dimensions of the diffuser model according to the submitted research for (Al-Quraishi et al., [17]). The aim of this study is to know the effect of the number of fins and their location inside the diffuser on improving the performance of the generated power.

II. METHODOLOGY

The research began with a review of numerous past studies and the selection of the optimal engineering parameter values. A methodology sequence was adopted in this paper to compare it with previous studies in the impact of depending on the previous model's diffuser geometry and numerical simulation tests of the three Models by changing the parameter of the number of turbine blades, in order to verify the effect of rotor position on the efficiency performance of wind turbines with an augmented diffuser on wind acceleration in the flanged diffuser by numerical simulation. The best configurations for the Ansys CFX modelling of the edged diffuser were then investigated.

A. Modelling of the Diffuser Augmented Wind Turbine (DAWT)

Parameter designs of the small-scale turbine model are listed in Table I while the section design parameters of the primary rotary blade are listed in Table II. Since the rotors of HAWT consist of three models including three-blade, two-blade, four-blade, they are designed separately and then assembled by SolidWorks program as shown in Fig. 1.

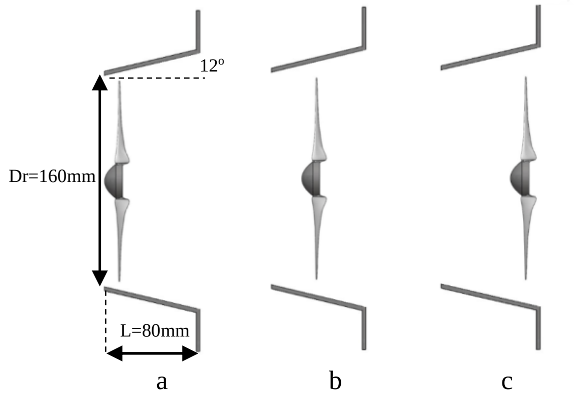

Figure 1. The position of the turbine relative to the diffuser: a: diffuser inlet, b: diffuser middle, c: diffuser end)

The preliminary turbine rotor model was created using conventional BEM theory (Blade element momentum theory), but because the effects of the diffuser on the aerodynamic performance of the blades were not taken into account, the turbine blade was redesigned using modified BEM Theory for DAWT (augmented diffuser wind turbine) [17]. The essential characteristics of a small-scale rotor design were kept the same as they were for the preceding rotor (as in Table 1).

B. 3D Simulation Domain

There are two domains; one stationary (for diffuser (for DAWT) and wind tunnel) and the rotating domain for a rotor. At the stationary domain, the inlet boundary of a normal speed was defined based on an operating wind velocity of 7 m/s. At the outlet, a relative static pressure equaled to 0 Pa was set. In the rotary domain (massive separation zone), angular velocity is defined in terms of rpm clockwise.

The frozen rotor between the stationary and rotating frames interface model is adopted [18].

The advantage of computational simulation among others is the ability to expose data in qualitative and quantitative forms. Also, the simulation analysis allows visualizing the fluid flowing around DAWT model, thus, providing exact information that is difficult to achieve in practice. In addition, the simulation provides an inexpensive wide range of test fields in comparison to practical experiments in terms of time or mechanism of manufacture that are difficult to do with simple tools. On the other hand, the simulation analysis provides the visualization for flow turbulence around the rotor and the mechanism of interaction between wind flow and rotor blades. Moreover, as one of this study's objectives was to examine the performance of DAWT in the simulation approach, subsequently, all cases involved a simulation analysis of the best models and compared with in terms of power coefficient. In order to obtain high accuracy in the flow check, the numerical model was implemented in 3-D field using CFX for a complete geometry of the diffuser model by placing the wind turbine in three locations inside the diffuser (diffuser inlet in the middle of the diffuser and in the outlet of the diffuser) to know the effect of the diffuser location on the performance as shown in Fig. 2. All publisher models are built using SolidWorks program.

The wind energy is extracted by the rotor of the turbine, which converts this energy into mechanical energy. Thus, the mechanical power (Pout) of a wind turbine is the product of torque (Q) and angular velocity (Ω) of the rotor and it can be accurately calculated by determining the angular velocity of rotation and rotating torque without any external load. The performance of a wind turbine is can be represented by the power coefficient (CP) which is defined as:

$$C_P = \frac{Q\Omega}{0.5\,\rho\,A\,V_\infty^3} \tag{1}$$

The most common method used to preview the power coefficient by graphing its values as function with Tip speed ratio (λ) which is defined as:

$$\lambda = \frac{QR}{V_\infty} \tag{2}$$

Where Q is rotor torque, Ω is angular velocity, ρ air density, A is rotor swept area, V_∞ is upstream wind velocity, and R is rotor radius.

TABLE I. THE MOST IMPORTANT FACTORS TO CONSIDER WHILE DESIGNING A SMALL-SCALE ROTOR

No.	Parameter	Details
1	Rotor diameter (Dr)	160 mm
2	Hub diameter (Dh)	26.1 mm
3	Blade span length (L)	80 mm
4	Blade root length (lr)	9.2 mm
5	Number of Blades	2, 3, 4
6	Angle of Attack (α)	5 °
7	Airfoil Type	NACA SD8000
8	Tip Speed Ratio (λ)	5
9	Wind speed (V^∞)	7, 10 m/s

1) Discretions of computational domain (Mesh and boundary conditions)

Unstructured 3-D tetrahedral meshing was employed due to its flexibility when solving complicated geometries [18]. A grid analysis (Mesh ANSYS) of the model by three trials to obtain optimal results. The skewness and orthogonal characteristics of the three-dimensional diffuser model grid were adopted as shown in Table II.

TABLE II. TRIAL OF THE GRID STATEHOOD OF A 3D DOMAIN

Trial No.	No. of nods	No. of elements	Skewness	Orthogonal quality
1	143893	781462	0.768	0.994
2	278071	1574254	0.796	0.993
3	543613	2844129	0.798	0.995

Table III shows the boundary and beginning conditions for the two ANSYS solvers in 2D and 3D diffuser domain models and the appropriate turbulence model type used in the analysis is *SST k-ω* relying on their use in previous studies [19], [20], [21]. At 25^o degrees celsius, the properties of air are relied upon as an ideal gas with a reference pressure of 1 atm in all domains. With a 10^{-5} convergence criterion, the flow was treated as isothermal and steady state. For CFX, the spatial discretization techniques had a high resolution. Despite the fact that CFX employs the high-resolution technique, which is a hybrid of the two, the results from CFX and second-order are in perfect accord [22].

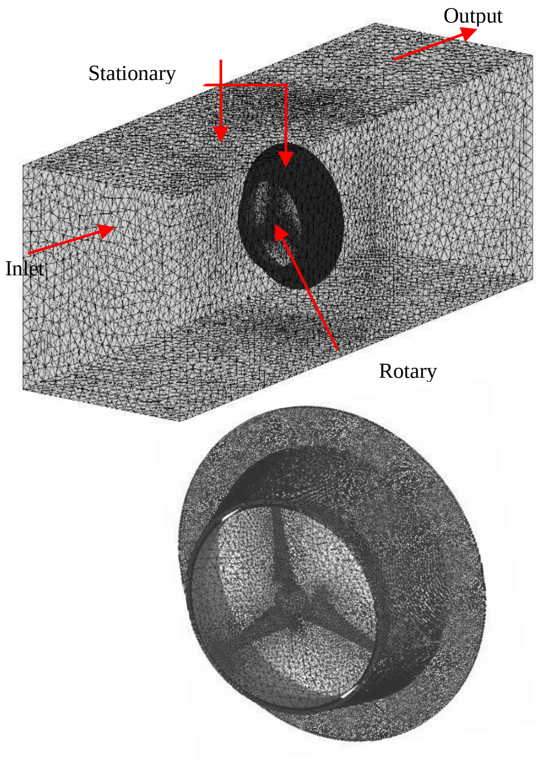

Figure 2. Generated mesh in the computational domain

TABLE III. THE BOUNDARY AND INITIAL CONDITIONS (3D SIMULATION)

Boundary conditions	**3D CFD Settings**
Inlet	Wind Velocity (Default intensity) (10, 7 m/s)
Output	Pressure 0 Pa (Open system)
No slip wall	All stationary domains
Symmetry	-
Turbulence model	*SST k-ω*

2) Model validation

Before presenting the simulation results for the best cases of this study for DAWT models and the effect of the change in the number of turbine blades on the performance of the horizontal wind turbine, the field of work must be examined to verify the validity of the results presented by the researcher and based on the best model used model based on the reference (Al-Quraishi et al.,[14]). So the validation procedure was accomplished first, by adopting the two best DAWT models through simulation in terms of power coefficient as relationship with tip velocity ratio using the test wind speed is (10 m/s) as shown in Fig. 3. From this figure, it can be seen that there was a good convergence between the experimental and simulation results within the acceptable range with a mean of less than 12%.

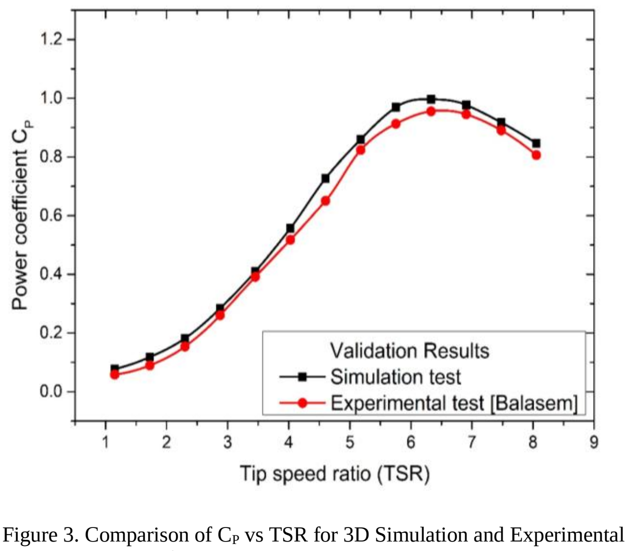

Figure 3. Comparison of C_P vs TSR for 3D Simulation and Experimental Test of the researcher (Al-Qureshi et al., [11]).

III. RESULTS AND DISCUSSION

It is very important to display the behavior of wind turbines with respect to the dimensionless aerodynamic quantity such as power factor and torque coefficient. This can be achieved by estimating such parameters as a function of the number of blades and the tip speed ratio. Therefore, this part analyzes the performance of the power coefficients showing the increase of the diffuser augmented wind turbine (DAWT) with the change in turbine locations in all cases. These coefficients were expressed as a function of the terminal velocity ratio by depending on the input wind velocity of the simulation domain test is 7 m/s as shown in Fig. 4, Fig. 5 and Fig. 6, in the case of C_P These graphs can be used to show how changing the number of turbine blades affects the outcome (two blades, three blades and four blades), and the effect caused by changing the turbine position from the diffuser on the wind speed energy (diffuser inlet, middle of the diffuser and end of the diffuser). The figures show the relationship between the power factor and the tip velocity ratio, which resulted that the optimum C_P in the case of the turbine site in the diffuser inlet is the highest among the other sites used and is located at an average tip speed ratio of 6.3. This means that the effect of changing the position of the diffuser in this range caused by the change in wind speed has an obvious effect on the maximum power extracted from the 4-blade wind turbine.

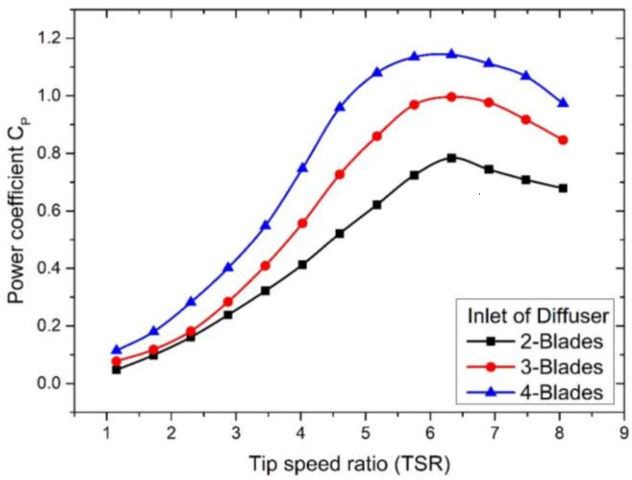

Figure 4. Comparison of C_P vs TSR 3D simulation with the parameter of blades number at diffuser inlet

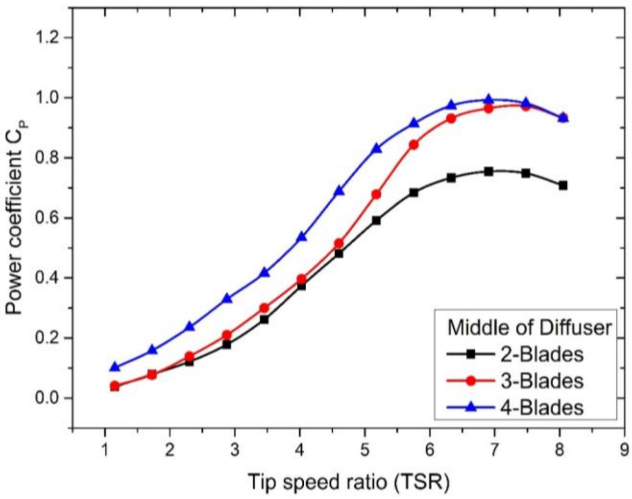

Figure 5. Comparison of C_P vs TSR 3D simulation with the parameter of blades number at diffuser middle

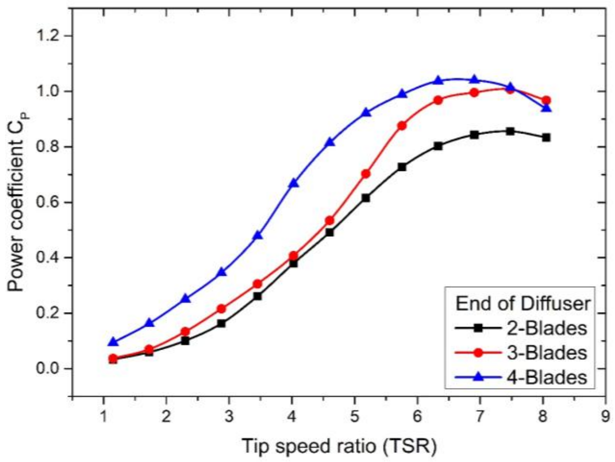

Figure 6. Comparison of C_P vs TSR 3D simulation with the parameter of blades number at diffuser end

Also, in this study, the number of four blades leads to an increase in the performance of the turbine and to obtain the optimum value of C_P, which means that the increase in the number of blades with the presence of the diffuser raises the efficiency of the turbine performance to varying proportions compared to the number of blades (2 and 3) with the tip speed ratios between (6-7). This can be explained by considering that the power generated is the product of the torque's angular velocity and the torque's angular velocity: the more blades, the higher the torque, assuming that the force in the wind is constant.

IV. Qualitative Visualization Analysis for DAWT

CFD post in ANSYS solver provides the ability for users to visualize the flow at any working condition and position, especially around the model. The 3D simulation used in this study provided information on the effects of flow around the models. This was presented in the flow scenario of the DAWT diffuser model in the ideal case for analytical tests on a four-blade wind turbine.

The flow was visualized for this model in terms of velocity contour, pressure contour, velocity streamlines, and turbulence kinetic energy at the same wind velocities, elected for visualizing flow through the diffuser, 7 m/s. As the visualization figures provided many details by looking at them, as a result, the statements on figures of visualizing models in this section were kept short and precise. Fig. 7 show the velocity contour at wind flow of 7 m/s at a longitudinal plane for the model (DAWT) with the different rotor positions, where there was a respectable increase in the velocity. The inclusion of a flange at the diffuser's exit contributed to this rise.

Fig. 8 show the pressure contours at a plane in the direction of flow at the same wind speed (7 m/s) for the different rotor positions. From the figure, it can be observed that there was a significant reduction in pressure in the area behind the rotor for DAWT model. As the rotor blades are the active element in the turbine, the pressure distributed on them is the basis that results in the transformation of the force in the wind to a torque force that can rotate the rotor, so the focus is set on this aspect. Moreover, the figures showed that there was a balanced and positive distribution of the pressure.

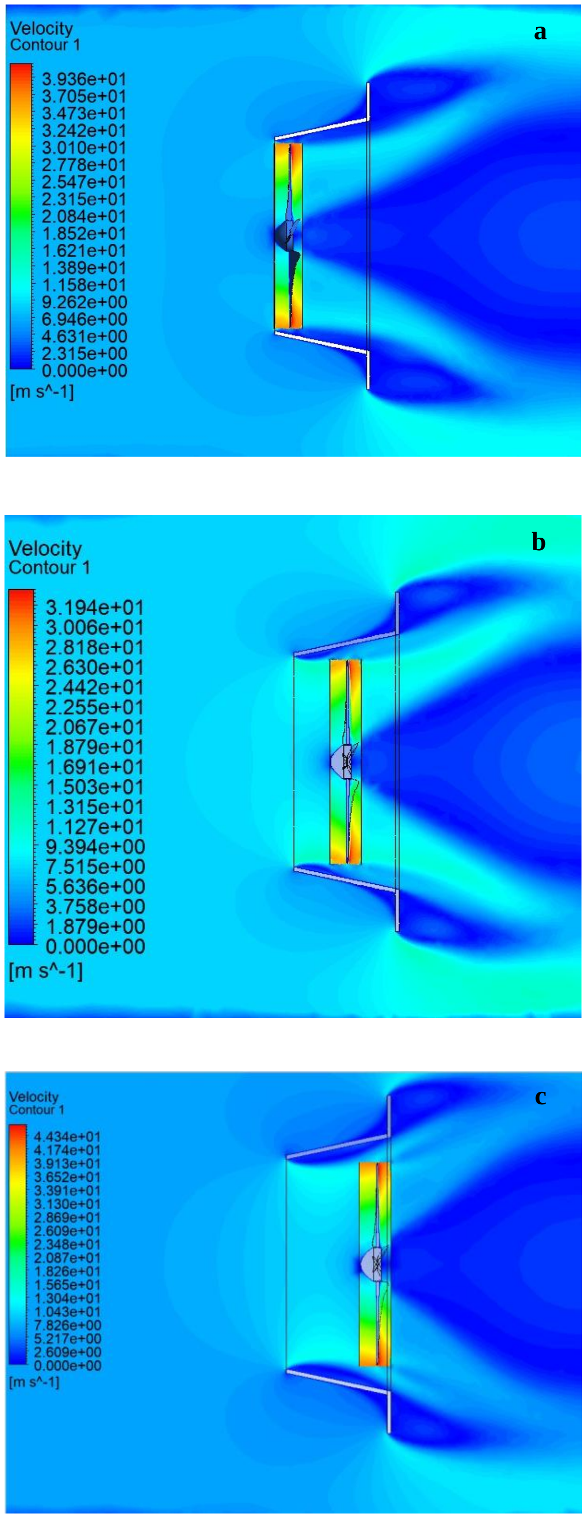

Figure 7. The behavior of a velocity contour at wind flow 7 m/s for rotor position:- a: diffuser inlet, b: diffuser middle, and c: diffuser end

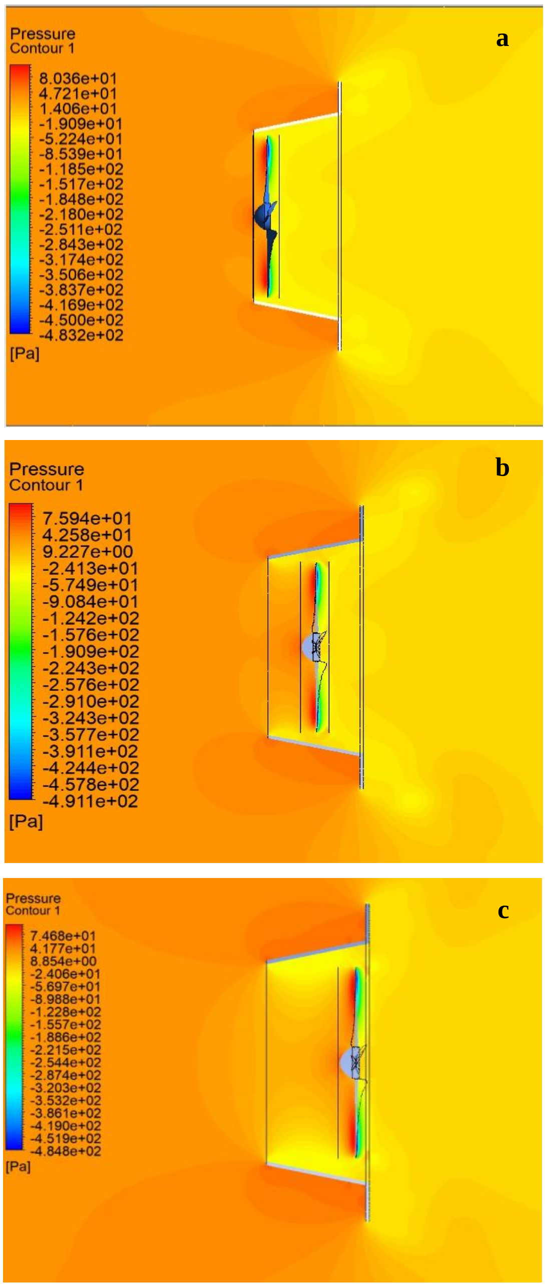

Figure 8. The behavior of a pressure contour at wind flow 7 m/s for rotor position: - a: diffuser inlet, b: diffuser middle, and c: diffuser end

V. Conclusion

The use of the DAWT concept has made a quantum leap in increasing wind energy production, compared to traditional wind turbines and especially small urban turbines. Therefore; the use of the flanged diffuser geometry is suitable to cover a small size model of HAWT, is capable of increasing the flow velocity at the proposed location of the rotor. Modified geometric models for a publisher with the same dimensions as for the researcher were adopted (Al-Quraishi et al.,[17]), and validated numerically by CFD simulation with an error rate of about 12% for the power coefficient curves; After that, two objectives were focused on in this study: first, the change in the turbine's position relative to the diffuser in three cases (the inlet of the diffuser, the middle of the diffuser and the end of the diffuser) and the second is the change in the parameter for the number of blades (2-blades, 3-blades and 4-blades) and the results were the position of the horizontal axis wind turbine reinforced with a diffuser at the inlet gives the highest performance compared to other cases. Where the increase in the power coefficient of the turbine at the inlet of the diffuser is (22%) compared to its position in the middle of the diffuser, while when compared with the outlet of the diffuser is (14%). As for the results of the parameter number of blades, the highest performance of the turbine is for the power coefficient curve is at four blades, where the percentage of increase is (23%) compared to three blades, while compared with two blades, the increase is (73%). But the good design must depend on the ease of maintenance and the cost of manufacturing. Therefore, the contribution of this study is to emphasize the researchers' use of three-bladed wind turbines because they are more suitable for this. Also, the suitable location of the wind turbine should be at the front of the diffuser (inlet side of the wind).

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

M. M. Shkhair, O. K. Jaber, and S. M. Al-Absi have designed and of all turbine and diffuser models for this study. M. M. Shkhair, O. K. Jaber, and S. M. Al-Absi have worked on numerical simulation of the models using the CFD-ANSYS program and write the paper. S. M. Al-Absi has supervised the research and development of the project and the paper writing phase. All authors have approved the final version.

References

[1] S. O. Mezan, S. M. Al Absi, A. H. Jabbar, M. S. Roslan, and M. A. Agam, "Synthesis and characterization of enhanced silica nanoparticle (SiO2) prepared from rice husk ash immobilized of 3-(chloropropyl) triethoxysilanea," *Mater. Today Proc*., vol. 42, pp. 2464–2468, 2021.

[2] A. Sadikin et al., "A comparative study of turbulence models on aerodynamics characteristics of a NACA0012 airfoil," *Int. J. Integr. Eng*., vol. 10, no. 1, pp. 134–137, 2018.

[3] J. N. Libii and D. M. Drah, "The influence of the lengths of turbine blades on the power produced by miniature wind turbines that operate in non-uniform flow fields," *World Trans. Eng. Technol. Educ*., vol. 10, no. 2, pp. 128–133, 2012.

[4] O. Igra, "Research and development for shrouded wind turbines," *Energy Convers. Manag.*, vol. 21, no. 1, pp. 13–48, 1981.

[5] A. D. Peacock, D. Jenkins, M. Ahadzi, A. Berry, and S. Turan, "Micro wind turbines in the UK domestic sector," *Energy Build.*, vol. 40, no. 7, pp. 1324–1333, 2008.

[6] S. Meri, A. Absi, A. Hasan, S. Oudah, and B. A. Al-, "An experimental test of the performance enhancement of Savonius turbine by modify inner surface of a blade," *Mater. Today Proceedings*, Elsevier, vol. Proceeding, 2021.

[7] B. A. Al-quraishi, N. Z. B. Asmuin., M. N. Nemah, and Salih Meri AR, "Experimental and simulation investigation for performance of a small-scale model of bare and shrouded HAWT," *Int. J. Mech. Eng. Technol*., vol. 10, no. 1, p. 434 449, 2019.

[8] S. Z. Roshan, S. Alimirzazadeh, and M. Rad, "RANS simulations of the stepped duct effect on the performance of ducted wind turbine," *J. Wind Eng. Ind. Aerodyn.*, vol. 145, pp. 270–279, 2015.

[9] B. Kanya and K. D. Visser, "Experimental validation of a ducted wind turbine design strategy," *Wind Energy Sci.*, vol. 3, no. 2, pp. 919–928, 2018.

[10] R. Acharya, "Investigation of differences in ansys solvers CFX and Fluent," *KTH, Mechanics*, 2016.

[11] Elsayed, Ahmed M. "Design optimization of diffuser augmented wind turbine," *CFD Letters*, vol. 13, no. 8, pp. 45-59, 2021.

[12] C. J. Bai, W. C. Wang, and P. W. Chen, "The effects of sinusoidal leading edge of turbine blades on the power coefficient of horizontal-axis wind turbine (HAWT)," *Int. J. Green Energy*, vol. 13, no. 12, pp. 1193–1200, 2016.

[13] A. M. El-Zahaby, A. E. Kabeel, S. S. Elsayed, and M. F. Obiaa, "CFD analysis of flow fields for shrouded wind turbine's diffuser model with different flange angles," *Alexandria Eng. J.*, vol. 56, no. 1, pp. 171–179, 2017.

[14] A. A. Salih Meri, H. Bin Salleh, M. Muayad, A. Mohammed, A. B. A, and H. S. S, "Experimental study of the performance of the elliptical savonius turbine and new design for blade shape Using A 3D printing technology," *Int. J. Mech. Mechatronics Eng. IJMME*, vol. 19, no. 04, pp. 85–89, 2019.

[15] S. S. Hamza, A. L. Emran, B. Ismail, M. Y. Yaakob, and S. M, "Influence of geometrical shape on the crashworthiness performance of tubular jute mat / epoxy composite specimens," *Int. J. Mech. Mechatronics Eng. IJMME-IJENS*, vol. 20, no. April, pp. 1–12, 2020.

[16] W. Koichi and Y. Ohya, "A simple theory and performance prediction for a shrouded wind turbine with a brimmed diffuser," *Energies*, vol. 14, no. 12, 3661, 2021.

[17] A. J. Balasem Al-Quraishi et al., "Improvement of a flanged diffuser augmented wind turbine performance by modifying the rotor blade aerodynamic design," *J. Adv. Res. Fluid Mech. Therm. Sci.*, vol. 72, no. 1, pp. 124–137, 2020.

[18] B. Kosasih and H. Saleh Hudin, "Influence of inflow turbulence intensity on the performance of bare and diffuser-augmented micro wind turbine model," *Renew. Energy*, vol. 87, pp. 154–167, 2016.

[19] Rahmatian, M. Ali, P. H. Tari, M. Mojaddam, and S. Majidi, "Numerical and experimental study of the ducted diffuser effect on improving the aerodynamic performance of a micro horizontal axis wind turbine," Energy, vol. 245, pp. 123267, 2022.

[20] R. Bontempo and M. Manna, "The Joukowsky rotor for diffuser augmented wind turbines: Design and analysis," *Energy Conversion and Management*, vol. 252, p. 114952, 2022.

[21] H. M. Elbakry, A. A. A. Attia, O. E. Abdelatif, and M. S. Zahran, "Simulation of diffuser augmented wind turbine performance," in *Proc. 2016 WORLD Congr. Sustain. Technol*, WCST 2016, pp. 40–48, 2016.

[22] L. Michal, K. Maciej, and J. Krzysztof, "Analysis and comparison of numerical methods for design and development of small Diffuser-Augmented Wind Turbine (DAWT)," in *IECON Proc. Industrial Electron. Conf.*, pp. 5525–5531, 2016.

Mohammed Mohsin Shkhair obtained his Bachelor's degree from Technical College / Al-Furat Al-Awsat Technical University, Najaf, Iraq in 2005. He received his Master's degree from Osmania University in Hyderabad, India, specializing in turbine machinery in 2015 and he is currently an assistant teacher and director of the electrical department at Shatra Institute / Southern Technical University. He has research interests in the field of heat transfer and renewable energy and has published research in those disciplines.

Oday Kdham Jaber obtained his B.Sc, M.Sc, and Ph.D. degrees in Mechanical Engineering from the College of Engineering at Basra University - Iraq in 2003, 2015, and 2000. He is currently a teacher and director of the automotive department at Shatra Institute / Southern Technical University, Iraq. His research interests include thermomechanical engineering, alternative energy, composites, mechanical design, and analysis and he has published research in the field of interest.

Saleh Mari Al-Absi was born in Al-Muthanna Governorate, Iraq on February 4, 1976. He received his Ph.D. in Mechanical Engineering from Universiti Tun Hussein Onn Malaysia (UTHM), Malaysia in November 2019, and his main field of study was Renewable Energy Engineering. He completed his master's studies at the Osmania University in Hyderabad, India in December 2013 his main field of study was Turbomachinery engineering. His current job is as a Chief Engineer in the field of energy engineering in the Department of Mechanical Engineering, Iraqi Cement State Company, Ministry of Industry and Minerals, Baghdad, Iraq. His research interests cover topics such as green energy, composites, nanomaterials, wind turbines, turbines, and mechanical analysis using CFD ANSYS. He has several research publications in the scientific fields mentioned above. He has 23 years of service in the manufacturing field. Multiple scientific research has been reviewed in several fields.