Journal of Technology and Exploitation in Mechanical Engineering
Vol. 3, no. 1, pp. 1–7, 2017

ISSN 2451-148X
Available online at: http://jteme.pl

Research article

CFD ANALYSIS OF THE AIR FLOW AROUND THE BLADES OF THE VERTICAL AXIS WIND TURBINE

Muhammed Musab Gavgali[1], Zbigniew Czyż[2], Jacek Czarnigowski[3]

[1] Faculty of Engineering, Necmettin Erbakan University, Dr. Mehmet Hulusi Baybal Cd. No:12, 42060 Konya, Turkey, e-mail: muhammedmusabgavgali@yandex.com
[2] Department of Thermodynamics, Fluid Mechanics and Aviation Propulsion Systems, Lublin University of Technology, 36 Nadbystrzycka Str., 20-618 Lublin, Poland, orcid.org/0000-0003-2281-1149, e-mail: z.czyz@pollub.pl
[3] Department of Thermodynamics, Fluid Mechanics and Aviation Propulsion Systems, Lublin University of Technology, 36 Nadbystrzycka Str., 20-618 Lublin, Poland, e-mail: j.czarnigowski@pollub.pl

Submitted: 2017-05-17 / Accepted: 2017-06-12 / Published: 2017-06-22

ABSTRACT

The paper presents the results of calculations of flow around the vertical axis wind turbine. Three-dimensional calculations were performed using ANSYS Fluent. They were made at steady-state conditions for a wind speed of 3 m/s for 4 angular settings of the three-bladed rotor. The purpose of the calculations was to determine the values of the aerodynamic forces acting on the individual blades and to present the pressure contours on the surface of turbine rotor blades. The calculations were made for 4 rotor angular settings.
KEYWORDS: vertical axis wind turbine, VAWT, CFD, aerodynamics forces, drag force, lift force

ANALIZA CFD PRZEPŁYWU POWIETRZA WOKÓŁ ŁOPAT TURBINY WIATROWEJ O PIONOWEJ OSI OBROTU

STRESZCZENIE

W pracy przedstawiono wyniki obliczeń opływu wirnika turbiny wiatrowej o pionowej osi obrotu. Trójwymiarowe obliczenia wykonano za pomocą programu ANSYS Fluent. Obliczenia przeprowadzono w warunkach stacjonarnych dla prędkości wiatru równej 3 m/s dla 4 ustawień kątowych wirnika z trzema łopatami. Celem przeprowadzonych obliczeń było określenie wartości składowych siły aerodynamicznej działającej na poszczególne łopaty oraz przedstawienie konturów ciśnienia na powierzchni łopat wirnika turbiny. Obliczenia przeprowadzono dla 4 ustawień kątowych wirnika.
SŁOWA KLUCZOWE: turbina wiatrowa o pionowej osi obrotu, VAWT, CFD, siły aerodynamiczne, siła oporu, siła nośna

1. Introduction

Wind energy in the world energy balance is very high and is constantly developing. Wind resources that can be used to generate electricity cover about four times more energy than it is consumed per year. Currently, special programs are being launched in Europe to promote this way of obtaining electricity and to seek more efficient solutions of the construction for wind turbines. The importance of wind energy usage is significantly rising, and what is more, modern wind turbines are being arisen to sell electricity to the power network [1, 2]. A constantly growing interest in wind

© Muhammed Musab Gavgali et al., Published by Polish Association for Knowledge Promotion, 2017
This is an Open Access article distributed under the terms of the Creative Commons Attribution License (CC-BY 4.0) (http://creativecommons.org/licenses/by/4.0)

turbines results also in an increasing number of scientific works on this matter every year. While determining the actual power, the mechanics of incoming wind mass flow on the rotor, aerodynamics of rotor planes and rotor efficiency should be considered in wind power plants [3, 4, 5, 6]. The efficiency depends on the wind turbine power coefficient Cp which determines how much power stored in the flowing air is converted by the wind turbine. Research based on wind turbines can be carried out in a wind tunnel or with the usage of numerical tools of computational fluid dynamics [7]. The former method requires an aerodynamic tunnel and a real research object. Accordingly, the process of preparing the wind turbine and test benches to measure values such as torque and rotor power is really expensive. In addition, there is a limit to the size of the target wind turbine so scaled objects (reduced) are frequently used in the wind tunnel research. Transferring these results to a real scale may be difficult. An example of implementing the aforementioned method [7] presents the results obtained by examining a wind turbine on the vertical axis rotation. The study was conducted in an open circuit wind tunnel Gunt HM 170. The research object is a rotor with blades capable of altering the surface of the active area (i.e. receiving wind kinetic energy). Research objects, such as rotors with different angles of divergence of blades, were made using a 3D powder printer ZPrinter® 450. The research results refer to the selected flow velocity of 6.5 m/s for three angles of divergence (i.e. 30°, 60°, and 90°) at variable rotational speed. Excellent opportunities give us numerical fluid mechanics tools. An example of the use of CFDs was shown in [8] where the three-dimensional unsteady numerical analysis had been performed in order to analyze the aerodynamic characteristics of a H-Darrieus vertical axis wind turbine with two straight blades.

2. Research object and methodology

Figure 1 shows the front view and isometric view of the wind turbine as a research object. It is a vertical axis wind turbine with three blades. For the CFD calculation we do not need a complete construction with every detail, such as a generator, a supporting structure etc.; therefor, the original object was simplified as seen in Figure 2. The input model was downloaded from the GrabCAD website to develop our research object in CATIA v5.

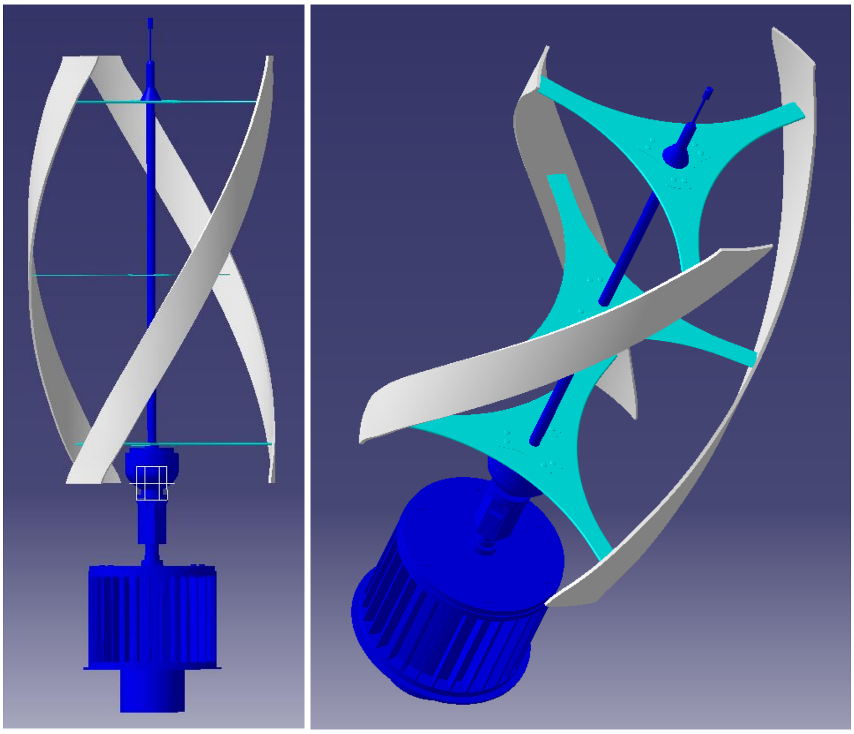


Fig. 1. Front view and isometric view of the wind turbine

In the next step, only three blades were separated in the Design Modeler. In order to investigate the overall flow through the rotor, it is not necessary to take into account the complete geometry. This approach allows us to calculate the case faster since this is a simplified mesh with a smaller number of elements.

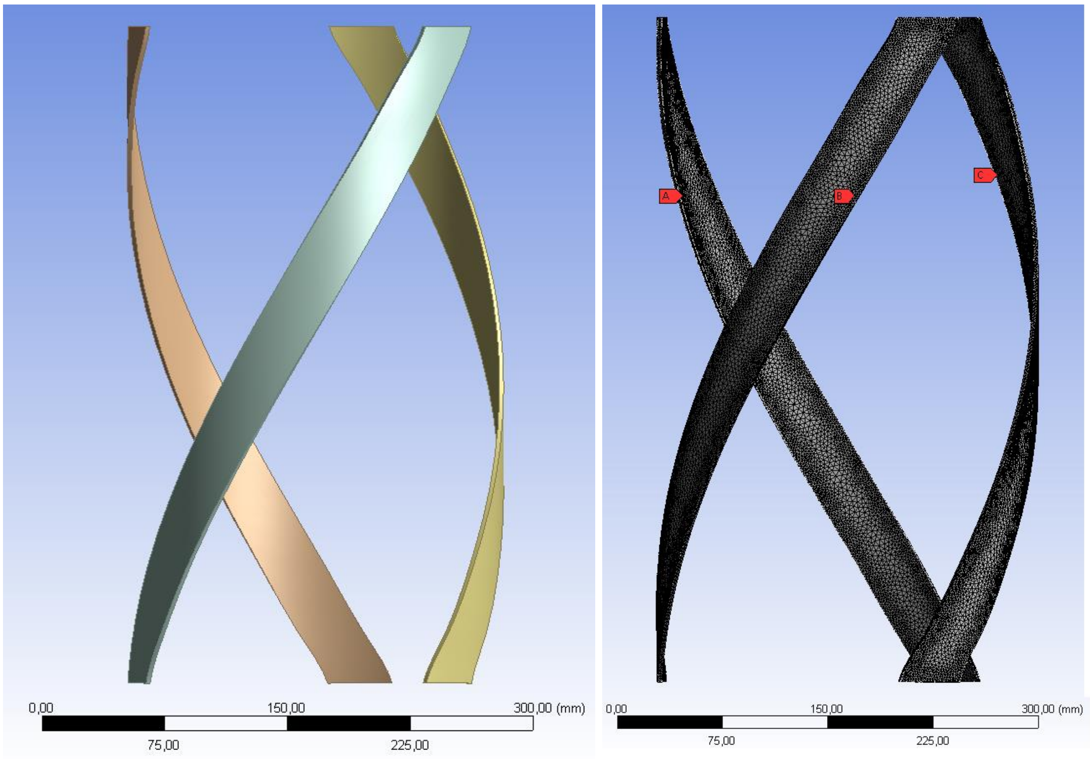


Fig. 2. Front view of the geometrical model of wind turbine blades and its discretized model

The preparing process of a geometrical model in order to develop a model for simulation calculations was followed by creating a suitable mesh of the surface of the blades. Accordingly, the model was imported into ANSYS Meshing software, and a *tetrahedrons* surface grid was created with the *patch conforming* algorithm (Fig. 2.). Table 1 presents general numerical analysis settings for ANSYS Fluent solver.

Table 1. General numerical analysis settings

Basic settings	Type of calculation	Pressure-based	
Dependence on time		Steady	
Turbulence model		k-omega (2-eqn) SST	
Materials	Gas	Air	
	Density	Incompressible–ideal–gas	
	Viscosity	Constant	
Boundary conditions	Inlet	Velocity	3 [m/s]
		Turbulent intensity [%]	1
	Outlet	Pressure - outlet [Pa]	Gauge pressure 0
		Turbulent intensity [%]	1

3. Results and Discussions

Figures from 3 to 10 demonstrate the pressure contours on the blade surfaces for the different rotor angular settings.

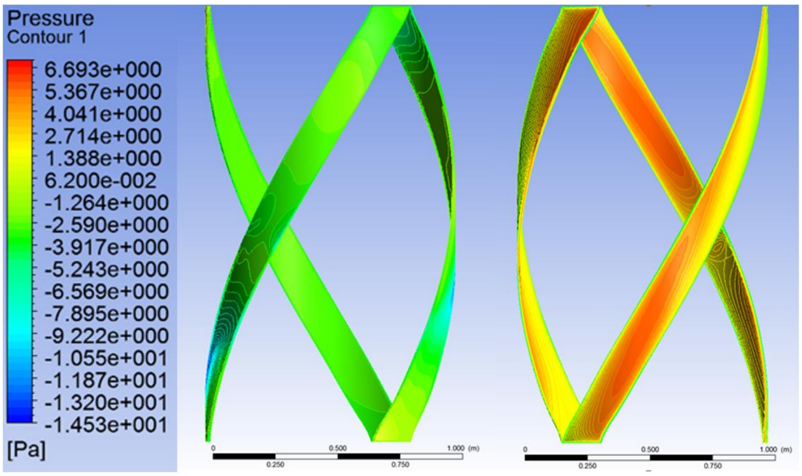


Fig. 3. View of the pressure contour on the wind turbine blades opposite to the X axis (left) and according to this axis (right) for the first angular position of 0°

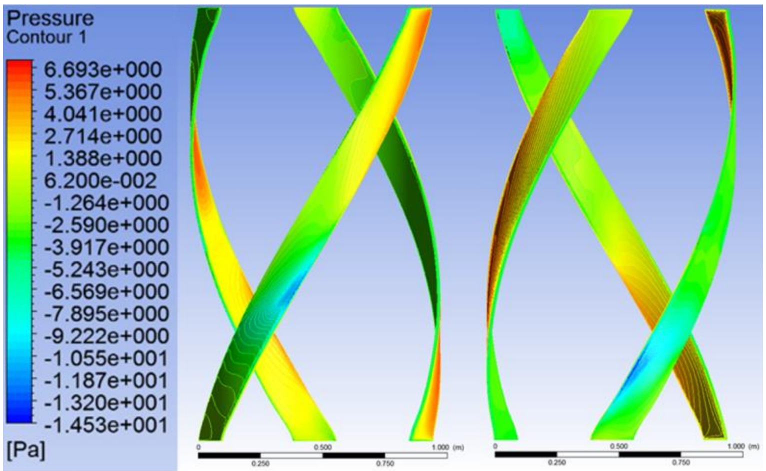


Fig. 4. View of the pressure contour on the wind turbine blades opposite to the Y axis (left) and according to this axis (right) for the first angular position of 0°

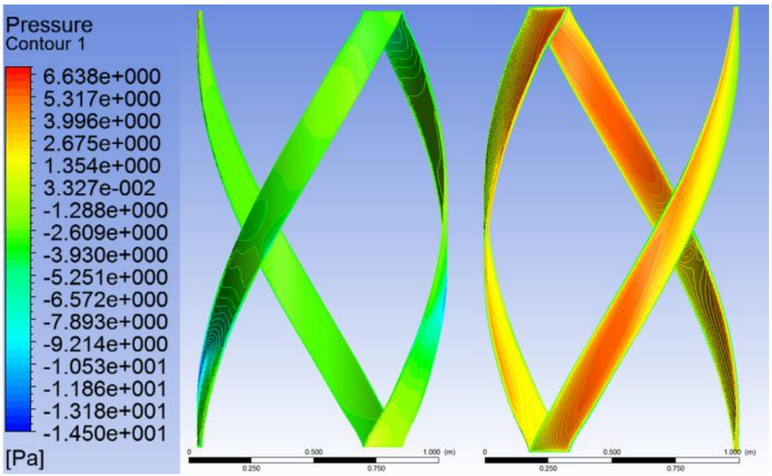


Fig. 5. View of the pressure contour on the wind turbine blades opposite to the X axis (left) and according to this axis (right) for the angular position of 90°

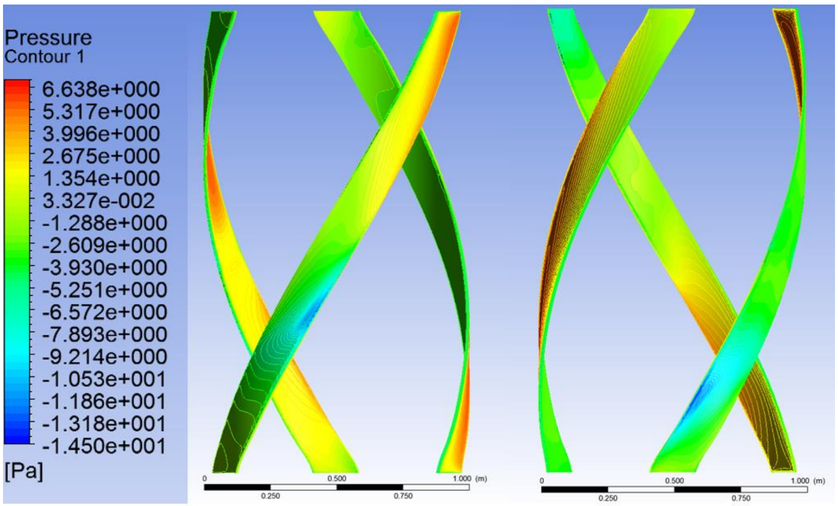


Fig. 6. View of the pressure contour on the wind turbine blades opposite to the Y axis (left) and according to this axis (right) for the angular position of 90°

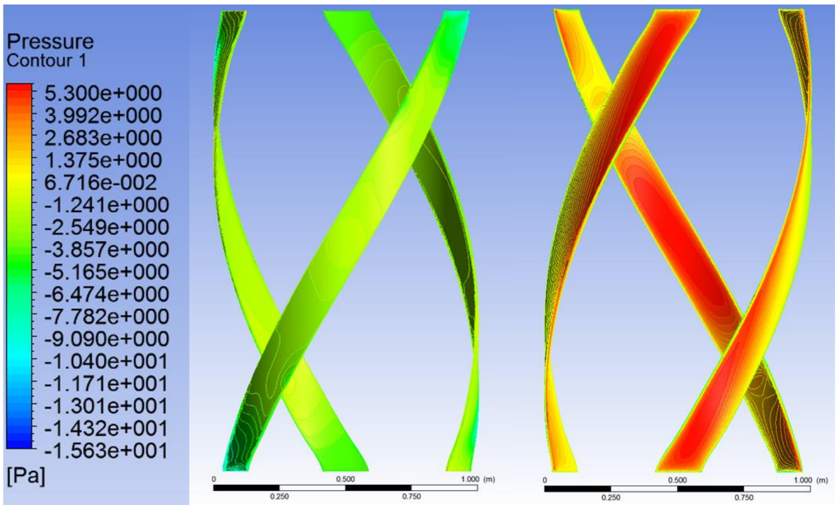


Fig. 7. View of the pressure contour on the wind turbine blades opposite to the X axis (left) and according to this axis (right) for the angular position of 180°

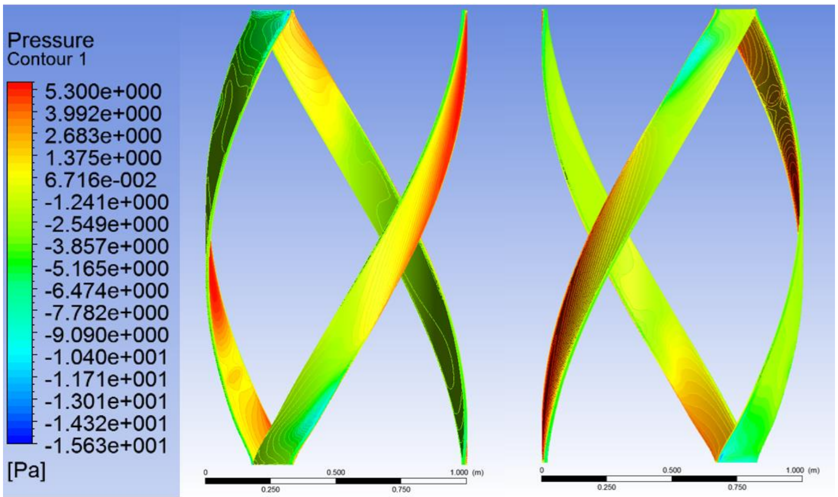


Fig. 8. View of the pressure contour on the wind turbine blades opposite to the Y axis (left) and according to this axis (right) for the angular position of 180°

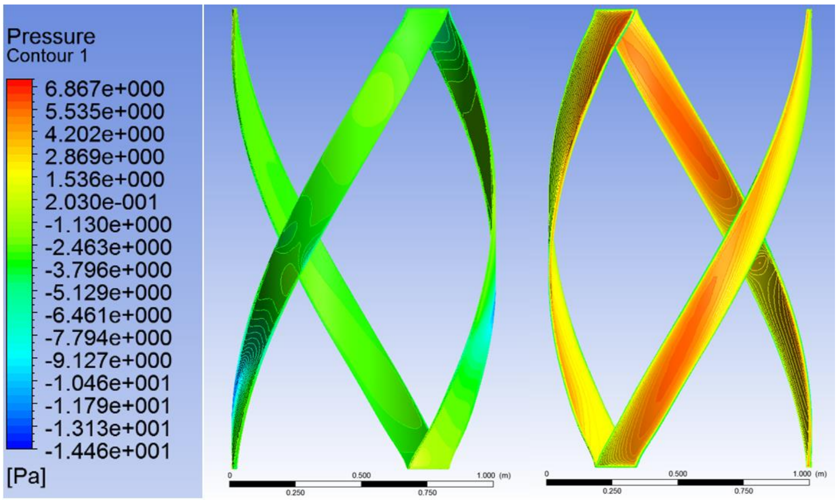


Fig. 9. View of the pressure contour on the wind turbine blades opposite to the X axis (left) and according to this axis (right) for the angular position of 270°

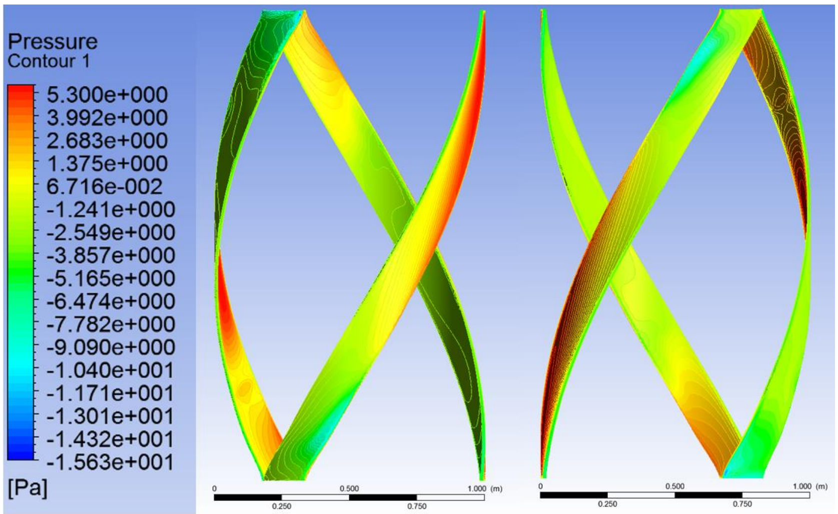


Fig. 10. View of the pressure contour on the wind turbine blades opposite to the Y axis (left) and according to this axis (right) for the angular position of 270°

Table 2 indicates the values of aerodynamic force acting on the individual blades for the considered rotor angles.

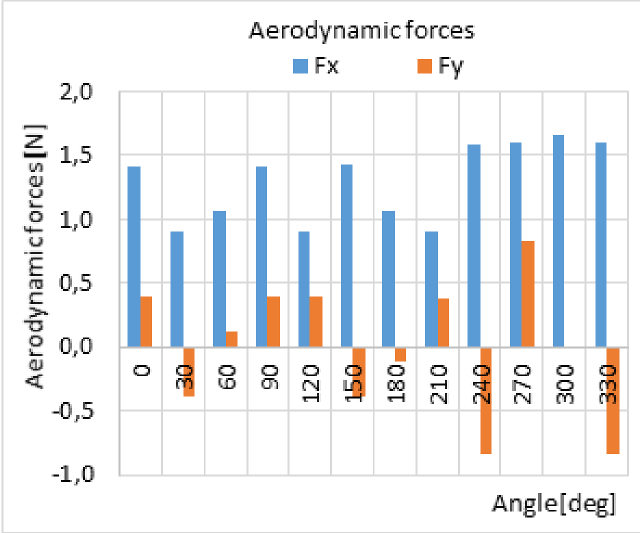
Table 2. Values of the forces acting on each of the turbine rotor blades

		Drag force [N]			
Name	**Axis**	**Angle 0°**	**Angle 90°**	**Angle 180°**	**Angle 270°**
Blade_1	X	1.4157	1.4161	1.0634	1.5935
	Y	0.3942	0.3952	-0.1143	0.8333
Blade_2	X	0.9081	0.9079	1.6652	0.9078
	Y	0.3905	0.3832	-0.0029	-0.3924
Blade_3	X	1.5900	1.5951	1.0598	1.4201
	Y	-0.8391	-0.8390	0.1112	-0.3957

By calculating the rotor with three blades for 4 angles, a total of 12 measurement points were obtained for different angles in the range from 0° to 330°, determined every 30°. The 360° angle coincides with an angle of 0° due to the rotation of the rotor by 90°, 180° and 270°, respectively. Table 3 was created after adjusting the force values as a function of the angle of rotation from 0 to 330.

Table 3. Aerodynamic forces depending on the angle

No.	Angle [°	Fx [N]	Fy [N]
1	0	1.4157	0.3942
2	30	0.9078	-0.3924
3	60	1.0598	0.1112
4	90	1.4161	0.3952
5	120	0.9081	0.3905
6	150	1.4201	-0.3957
7	180	1.0634	-0.1143
8	210	0.9079	0.3832
9	240	1.5900	-0.8391
10	270	1.5935	0.8333
11	300	1.6652	-0.0029
12	330	1.5951	-0.8390



4. Conclusion

The calculations give the results of the airflow around the wind turbine vertical axis. The three-dimensional calculations were performed using ANSYS Fluent. The calculations were made at steady-state conditions for a wind speed of 3 m/s for 4 angular settings of the three-bladed rotor. This research enables us to determine the values of aerodynamic forces acting on the individual blades and the pressure contours on the surface of turbine rotor blades. The calculations were made for 4 rotor angular settings. Two components of the aerodynamic force in the X and Y direction were read to compare these forces. The component of the aerodynamic force in the X direction assumes positive values throughout the total range, while the component Y is variable. The maximum value of drag force for the considered rotor (three blades) is 3.92 N (Tab.1.). This is the force that results only from the blades without any other structural components that would certainly increase this value.

5. References

[1] G. Jastrzębska, *Odnawialne źródła energii i pojazdy proekologiczne*. WNT, Warszawa, 2009.
[2] W. Lewandowski, *Proekologiczne odnawialne źródła energii.* WNT, Warszawa, 2010.
[3] A. Flaga, *Siłownie wiatrowe*, Wydawnictwo PK, Kraków, 2012.
[4] W. Jagodziński, *Silniki wiatrowe*. PWT, Warszawa, 1959.
[5] F. Wolańczyk, *Elektrownie wiatrowe*, Wydawnictwo KaBe, Krosno, 2009.
[6] D. Wood, *Small wind Turbines-Analysis, design and Application*. Springer-Verlag London Limited, 2011.
[7] Z. Czyż, Z. Kamiński, "The characteristics of the operating parameters of the vertical axis wind turbine for the selected wind speed", *Advances in Science and Technology—Research Journal*, no. 1, vol. 11, p. 58-65, 2017, https://doi.org/10.12913/22998624/68469.
[8] S. Joo, et al., "Aerodynamic characteristics of two-bladed H-Darrieus at various solidities and rotating speeds", *Energy*, 2015, http://dx.doi.org/10.1016/j.energy.2015.07.051.