DOI: 10.31489/2022NO2/65-69
UDC 620.92; 533.697.6; 004.94

INVESTIGATION OF AERODYNAMIC THRUST FORCE OF THE WIND POWER PLANT WITH COMBINED BLADES

Tleubergenova A.Zh.[1], Dyusembaeva A.N.[1], Tanasheva N.K.[1], Minkov L.L.[2], Mukhamedrakhim A.R.[1]

[1] E.A. Buketov Karaganda University, Karaganda, Kazakhstan, shymkent.a7@mail.ru

[2] National Research Tomsk State University, Tomsk, Russia

In this article, a wind power plant with a horizontal axis of rotation operating under conditions of variable wind speeds is considered. For this purpose, a mock-up of a wind power plant with rotating combined blades was made. During the experiments, the angle of the fixed blade relative to the cylinder changed from 0° to 60°, in increments of 15 °. The air flow rate varied, from 3 to 12 m/s. The analysis of the results of the experiment on the change of the rotation frequency from the air flow velocity of the wind power plant is carried out. When changing the position of the fixed blade (0°, 15°, 30°, 45°, 60°) the value of the thrust force changes relative to the air flow in direct proportion. As the air flow velocity increases, the rotation frequency of the wind wheel increases linearly. It was found that when the fixed blade was positioned at an angle of 60 degrees, with a maximum air flow velocity of 12 m/s, the thrust force reached 2.06 N. Due to the combined use of two lifting forces, such as a cylinder and a fixed blade, increased thrust values are observed. The results obtained are useful when creating prototypes of a wind power plant with combined blades.

***Keywords**:* wind power plant, flow velocity, combined blade, wind tunnel T-1-M, thrust force, rotational speed.

Introduction

Central Asia belongs to the regions where there are favorable conditions for the use of wind energy. The republics located in this region have huge, almost inexhaustible reserves of wind energy [1]. Wind power industry of Kazakhstan continues its dynamic development. Our country, following the global trend, is systematically working to increase the number of renewable energy power plants. Therefore, it faces the same challenges as other types of power plants using alternative energy sources. First of all, it is currency risk, stabilization of legislation, development of local content and small generation [2].

The use of wind turbines for electricity generation is the most efficient way to utilize wind energy. The efficiency of converting mechanical energy into electrical energy in an electric generator is usually up to 95%, and the loss of electrical energy during its transmission does not exceed 10%. The requirements for the frequency and voltage of the generated electricity depend on the characteristics of consumers of this energy [3]. The use of installations and devices using renewable and other new energy sources is now becoming especially important due to the problems caused by the so-called energy crisis, the shortage of hydrocarbon fuel, the tasks of saving it and environmental degradation [1-3].

Wind turbines are divided into installations with a horizontal or vertical axis of rotation. It is necessary to find out which of these wind turbines are most adapted to work in the conditions of the wind regime of the Republic of Kazakhstan. It should be noted that in most of the leading countries in the field of wind energy, wind turbines with a horizontal axis of rotation are used, which, as a rule, are a tall tower with long thin blades and a large diameter of the wind turbine. The blades have a flat convex or other similar profile, and the lifting force effect (the pressure difference on the opposite surfaces of the blades) is used as the basis of their operation [4]. The main problem that one has to face when using wind energy for energy supply to consumers is the variability of wind speed [5]. In recent years, there has been a growing demand for the development of renewable energy sources, the use of which minimizes environmental problems. Among alternative energy sources, wind generators are one of the most common. [6].

Of particular interest are rotating cylindrical combined wind turbines that operate efficiently at low wind speeds [7]. To improve the efficiency of such a wind turbine, it is necessary to study the aerodynamic characteristics of its elements, i.e., the system of transverse rotating cylinders, ways of optimization.

Accordingly, this work is relevant from a scientific point of view, in practical application. Previously, reviews of scientific research on the development and creation of wind turbines with horizontal and vertical axes of rotation were studied in detail. Works of domestic scientists were studied. A diffusor-type wind power plant is known, developed by the Doctor of Technical Sciences, professor Baishagirov H.Zh. [8].

At the Institute of Mining named after Kunaev D.A., under the leadership of Buktukov N.S. a promising design of the «Buktukov WPP» was developed [9], in which the change in the area of the swept surface occurs not by shifting the half-cylinders, but by turning, which allows a significant increase in power (many other domestic studies on the development of wind turbines were also studied in detail). As a prototype of the aerodynamic element that creates the Magnus effect on the blades of a wind turbine, the aerodynamic element described in [10] was adopted. The disadvantage of this wind turbine is the huge consumption of electricity for the operation of the drive. A distinctive feature in this work from the previous ones is the mutual combination of two different blades (rotating cylinders and fixed blades), which ensures high aerodynamic quality of the wind turbine.

Comparisons were made with experimental data with other authors of papers that describe studies with wind turbines with a horizontal axis of rotation. This wind turbine is unique compared to others, since the rotation of the wind wheel and the generation of wind energy starts from 3 m/s of air flow.

1 Experimental methodology

The purpose of this work is to analyze experimental studies of the aerodynamic characteristics of the movement of a horizontally-axial rotating cylindrical combined wind turbine in a variable flow. The research work was carried out in the laboratory «Aerodynamic Measurements» of the research Center «Alternative Energy» of the Faculty of Physics and Technology. A model of a rotating cylindrical combined wind turbine was developed, which was subsequently studied at different wind speeds in a transverse air flow.

Figure 1 shows an image of the location of the experimental installation on the working part of the wind tunnel, where the fixed blade is located at an angle in different directions relative to the axis of rotation of the cylinder.

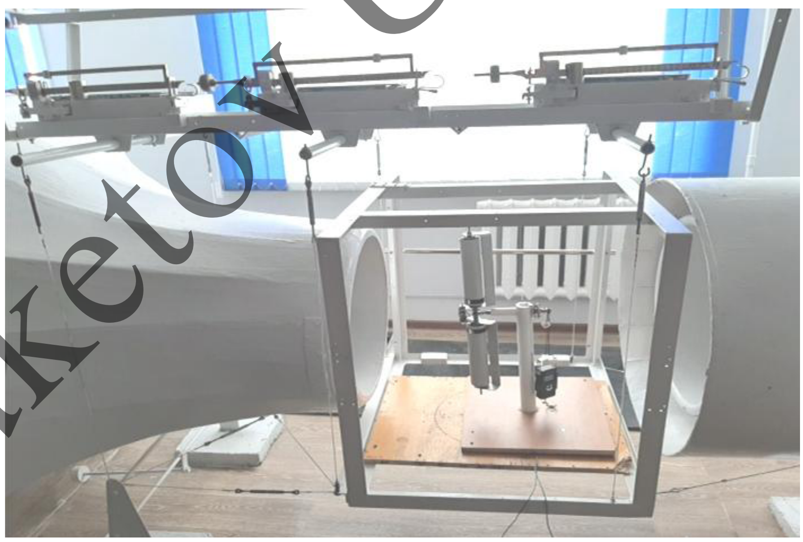
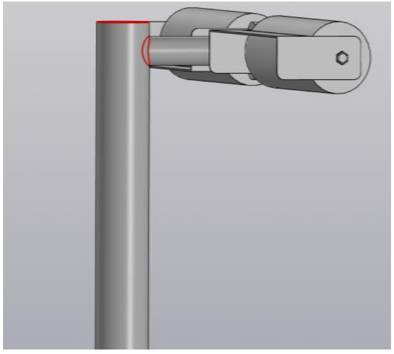


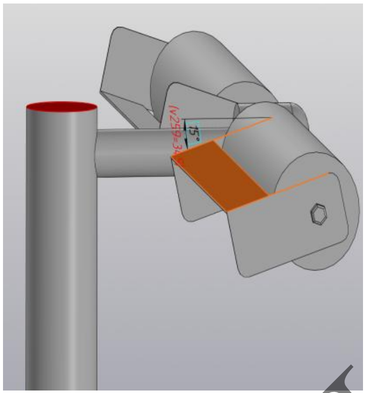
Fig.1. The location of the experimental installation on the working part of the wind tunnel

The test sample is placed in the working part of the wind tunnel and attached to the aerodynamic scales using a thin metal tensioner to reduce the resistance of auxiliary elements. Figure 2 shows how a fixed blade forms an angle (0°, 15°, 30°, 45°, 60°) relative to the distance of the axis of rotation of the cylinder. The tests were carried out with a horizontal axial combined wind turbine with a flat cylindrical rotation.

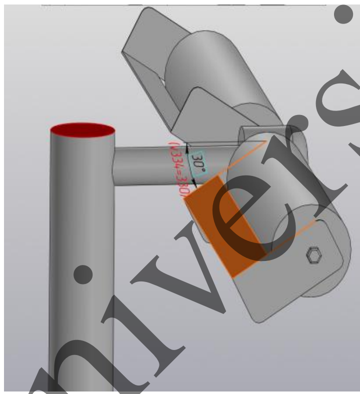
The air flow velocity varied from 3 to 12 m/s, the total diameter of the wind wheel D = 50 sm, the diameter of the cylinders d= 0.5 sm, the length of the cylinders 21 sm, the length of the fixed blade 23 sm.



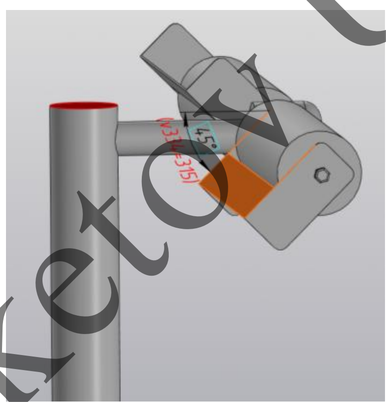
a) 0 degree



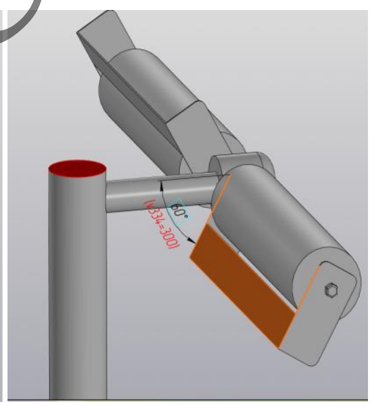
b) 15degree



c) 30 degree



d) 45degree



e) 60 degree

Fig. 2. Two-bladed cylinders with fixed blades

2 Research results

The aerodynamic characteristics of this model are determined - the thrust force and the rotational speed of a rotating cylindrical combined wind turbine at flow rates from 3 m/s to 12 m/s. As the wind speed increases, we see that the rotation frequency of our wind turbine also increases, which can be seen in the graph below. We determine the speed of rotation using a contactless tachometer (Fig 3).

Figure 4 shows a graph of the dependence of the thrust force of the layout on the wind speed. In Figure 4, we see an increase in the thrust force as the flow velocity increases from 3 m/s to 12 m/s. As can be seen from the dependence, with a maximum air flow velocity of 12 m/s, the thrust force values reached 0.9 N at 0 degrees, 0.97 N at 15 degrees, 1.29 N at 30 degrees, 1.09 N at 45 degrees, 2.06 N at 60 degrees, then the thrust force stabilizes, i.e. no increase is observed.

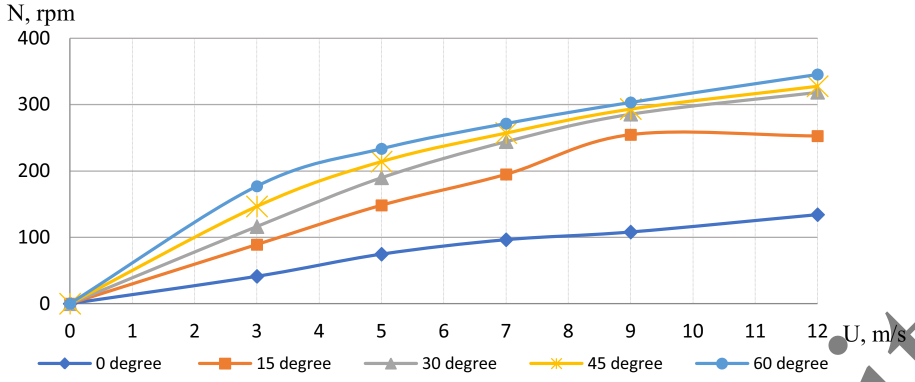


Fig. 3. Dependence of the rotation frequency of the layout on the wind speed

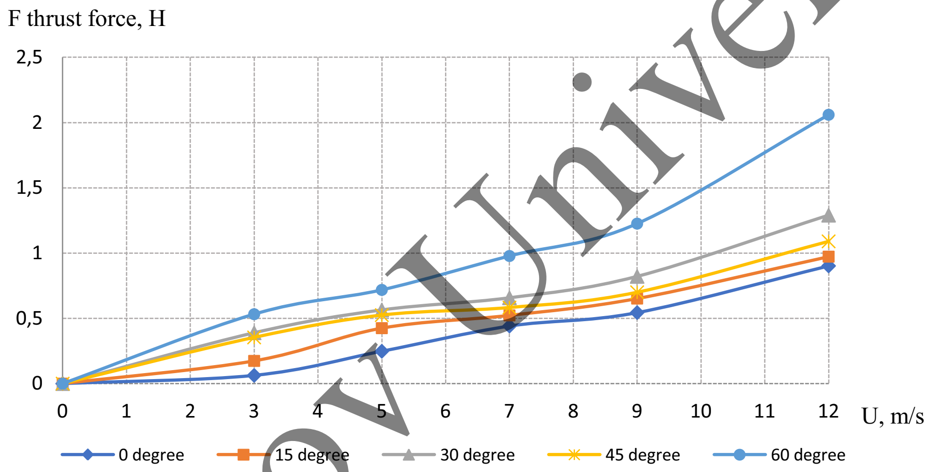


Fig.4. Dependence of the thrust force of the layout on the wind speed

Changing the angle of inclination of the fixed blade changes the curvature of the profile. Thus, it becomes possible to increase the traction force in an effective way. In the frontal part of the cylinder up to the point of separation of the boundary layer, there is a gradual delamination of the experimental data for different aspect ratios and inclination of the fixed blade. With an increase in the length of the cylinder, the value of dimensionless pressure at a fixed angle decreases, a gradual transition from the pressure distribution characteristic of spatial motion – flow around the cylinder to the pressure distribution characteristic of plane motion – flow around an infinitely long cylinder is manifested. In this case, this angle where there is a deterioration in the rotation of the blades is 45 degrees, where the thrust force decreases.

Further, with a change in the angle of inclination of 30 and 60 degrees, a gradual increase in the thrust force is observed, which is a positive result for the rotation of the blades.

Since we know that when the wind speed increases, the lifting force also increases, we can conclude that when the wind speed increases, the thrust force also increases, since the thrust force manifests itself in the pressure drop over the cylinder. The lower part of the cylinder operates at high pressure, while the upper part operates at low pressure. The pressure difference from above and below causes the thrust force.

Conclusion

Based on the results of experimental studies, the following conclusions can be drawn:

- A mock-up of a wind power plant with combined blades, in the form of a rotating cylinder and fixed blades, has been developed and created in order to increase the thrust force of the wind turbine.
- The novelty of this work is the optimal choice of operating and geometric parameters in the form of rotating cylinders and fixed blades, as well as the angle of inclination of the non-rotating blade (optimal degree of inclination).
- Experiments were carried out to study the thrust force and rotation frequency of the wind wheel depending on the change in wind speed, at different angles of the fixed blade relative to the cylinder.
- It is determined that at the set angle of inclination of the fixed blade of 60 degrees and at a wind speed of 12 m/s, the maximum values of the rotation speed of the wind wheel of 350 rpm and the thrust force of 2.06 N are obtained.

The practical application of the work is that due to the addition of fixed blades by the wind wheel, a more complete use of wind energy is provided during rotation. The proposed wind turbine with combined blades is effective because it starts the rotation of the wind wheel from 3 m/s. This wind turbine is suitable for autonomous alternative power supply in the field.

Funding

The work was carried out with the financial support of the Science Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan (IRN AP14972704 "Numerical study of a new design of wind turbine blades with a horizontal axis of rotation").

REFERENCES

1 Yuan Z., Liang F., Zhang H., Liang X. Seismic analysis of a monopile-supported offshore wind turbine considering the effect of scour-hole dimensions: Insights from centrifuge testing and numerical modelling. *Ocean Engineering*, 2023, 283, pp. 115067. doi:10.1016/j.oceaneng.2023.115067

2 Karatayev M., Clarke M.L. Current energy resources in Kazakhstan and the future potential of renewables: A review. *Energy Procedia*, 2014, 59, pp. 97-104. doi: 10.1016/j.egypro.2014.10.354

3 del Campo V., Ragni D., Micallef D., Diez F. J., Ferreira C. S. Estimation of loads on a horizontal axis wind turbine operating in yawed flow conditions. *Wind Energy*, 2015, 18(11), pp.1875-1891. doi: 10.1002/we.1794

4 Lotfi R., Mardani N., Weber G.W. Robust bi- level programming for renewable energy location. *International journal of energy research*, 2021, 45(5), pp. 7521-7534. doi: 10.1002/er.6332

5 Tanasheva N.K., Sakipova S.E., Minkov L.L.,Bakhtybekova A.R., Shuyushbaeva N.N., Burkov M.A. Study of aerodynamic characteristics of a cylindrical blade with deflector. *Eurasian Physical Technical Journal*, 2021, 18(3 (37)), pp.48-52. doi: 10.31489/2021No3/48-52

6 Manyonge A.W., Ochieng R.M., Onyango F.N., Shichikha J.M. Mathematical Modelling of Wind Turbine in a Wind Energy Conversion System. *Applied Mathematical Sciences*, 2012, Vol. 6 (91), pp. 4527–4536.

7 Tanasheva N.K., Kunakbaev T.O., Dyusembaeva A.N., Shuyushbayeva N.N., Damekova S.K. Effect of a rough surface on the aerodynamic characteristics of a two-bladed wind-powered engine with cylindrical blades. *Technical Physics*, 2017, 62 (11). pp. 1631-1633. doi: 10.1134/S1063784217110299

8 Baishagirov H.J. *Wind power plant*. Publ. 2012, 4, 4p. [in Russian]

9 Bukatov N.S., Buktukov B.J., Moldybaeva G.J., Iakov A.K. *Wind farm Butukova 6 (option).* Publ. 2013, 12, 4p. [in Russian]

10 Bychkov N.M. Wind turbine with Magnus effect: 1 Results of model studies. *Thermophysics and aeromechanics*. 2004, –11 (4), pp. 583-596.

Article accepted for publication 03.05.2023