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DEVELOPMENT OF A VORTEX WIND DEVICE

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The relevance of the research is related to the development of a new type of renewable energy source – a vortex wind device with a vertical axis of rotation without wind guidance mechanisms. The main purpose of the study is to develop a vortex wind turbine using mathematical modeling of vortex motion and laboratory experiments on the model. The object of the study is a vortex wind device consisting of a concentrator with curved channels, inside which there is a wind wheel, and a vertical pipe mounted on the concentrator.

The calculations are based on the method of modeling large vortices with the solution of averaged Navier-Stokes equations. As a result of the research, the velocity distribution in the concentrator, inside the structure and the discharge pipe were obtained. The computational experiment shows that the narrowing channels of the concentrator create a stable vortex motion inside the structure and the vertical pipe. The methods used for calculating turbulent flows allow to study aerodynamic processes in wind turbines with a vortex effect. The absence of a rotary mechanism reduces the risks of breakdowns of rotational elements due to their absence. The concentrator perceives the wind flow from any side and creates a vortex motion inside itself due to curved channels. The outlet openings of the curved channels are directed to the blades of the wind wheel, which increases the maximum transfer of wind flow energy to the blades of the wind wheel. The vortex motion inside the concentrator creates a steady rotation of the wind wheel. An additional important point is the removal of the exhaust air flow from the vortex wind device. Existing wind farms have wind guidance mechanisms, which complicates the design, a stable rotation mode of the wind wheel is not created. All these problems of operating stations can be solved with the help of a vortex wind device

Keywords: flow twist, steady vortex motion, vertical thrust, exhaust air discharge, increased throughput

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1. Introduction

The relevance of this scientific topic is related to the development of renewable energy sources for low-carbon and sustainable development. Wind turbines are an important area of renewable energy. Three-bladed wind farms with a horizontal axis of rotation, which were developed at the beginning of the last century, have found wide application. Despite their widespread distribution, they have a limitation in the direction and magnitude of wind speed. Precipitation and low temperature negatively affect the operation of these turbines, which are the causes of accidents at wind farms due to heavy gusts of wind, snowfall and fires associated with lightning [1]. The turbulent nature of the wind flow creates uneven rotation of the wind wheel and unstable energy production. In this regard, additional equipment is required for energy storage so that the station can produce energy with constant characteristics. Low operational efficiency and additional costs for auxiliary equipment increase the cost of the station. To improve the efficiency of wind farms, research is being conducted in various areas. They are mainly associated with a wind turbine with a vertical axis of rotation. In order to increase efficiency, guide walls were used to direct the wind to the blades, which subsequently made it possible to create a vortex motion. Research on the stabilization of the station due to stable rotational motion and the development of a vortex wind device are relevant.

Climate change, environmental degradation, social tension of society due to crisis phenomena and turbulence in the energy markets force all mankind to take measures to decarbonize the economy, the widespread use of renewable energy sources (RES), to develop competencies for the use of hazardous technologies (nuclear, hydrogen).

The development of wind power was associated with horizontally axial wind turbines. To increase the efficiency of these turbines, their manufacturers increased the unit turbine power due to the height of the tower and the length of the blades of the wind wheel. The large dimensions of wind farms affect the flora and fauna, as well as the civilian population. In this regard, certain trends have emerged against the expansion of the construction of wind farms near settlements and forests. Another negative aspect in the development of wind power is accidents due to heavy gusts of wind and fires associated with lightning [1].

In practice, it turned out that existing wind farms have a number of disadvantages that lead to their inefficient operation and create unregulated and oscillatory energy production, which negatively affects the overall operation of the power system. Rotational motion is widely known in science and is used in various sectors of the economy. For example, the flywheel receiving rotation stabilizes the engine, the rotational movement of the bullet increases the accuracy of shooting, the vortex movement in the mine spillway increases its throughput, providing a stable flow inside the spillway, and also improves the cleaning of the flow in the hydrocyclone, creating a stable rotation in the cone.

Therefore, research on the development of a wind turbine using swirling walls that ensure stable vortex motion and efficient operation of the wind device is relevant.

2. Literature review and problem statement

In [2], wind devices with a vertical axis of rotation with fixed vertical blades are considered. The main advantage of these designs is the absence of wind guidance mechanisms. At the same time, their limitation is the low speed and low efficiency of the turbine due to the high resistance of the wind wheel. When the wind wheel rotates, the stationary blades change their wind age to the wind. If one blade falls under the action of the wind flow, then the other blades move opposite the flow or at an angle to it, which causes the resistance of the wind wheel and reduces the efficiency of the turbine. The document [3] presents the results of a study on improving the efficiency of a wind wheel by increasing the walls in a wind turbine. Some of them, which are located on the outside of the wind wheel, direct the flow into the inner walls and thereby increase the degree of reception of wind energy by the blades, but this leads to an increase in the wind wheel's resistance and wind age. But there were unresolved issues related to the reliability of the design. This becomes especially dangerous in an unstable wind flow with high turbulence and eddy currents. The company [4, 5] Helix Wind Corporation has developed a wind farm to power cellular base stations, the blades of which are helical spirals with transverse furrows. Such blades are a poorly streamlined body and are designed for low wind speeds and low power, and also cannot be used for industrial energy production. The reason for this may be the inability to increase the width of the blades due to the cantilever tension at the attachment point of the wind wheel.

The development of this direction is the development of the German company Turbina Energy AG in the form of a turbine with a vertical axis of rotation [6], in which there are fixed external walls and walls of the same size on the wind wheel. The fixed outer walls direct the wind flow to the blades, thereby ensuring the rotation of the wind wheel. It is shown that an unstable wind flow does not create a stable movement of the wind wheel. The reason for this may not be the stability of the wind flow, the uneven pressure of the flow on the blades of the wind wheel, the fundamental impossibility of removing the exhaust air.

The way to overcome these difficulties can be the use of a concentrator at the Georgia Institute of Technology (Atlanta, USA), which allowed the development of a vortex wind device Solar Vortex [7]. Simpson, the developer of Solar Vortex, tested a model of this design. It is shown that with an increase in the diameter of the turbine, the energy output increases dramatically. But there were unresolved issues related to the growth of energy, the inefficient operation of the wind wheel, and the role of lift was not considered. The reason for this may be the placement of a wind wheel across the wind flow, which creates additional resistance and reduces the carrying capacity of the structure.

In work [8], the results of a study of a vortex wind power plant, which uses low-potential air flows that are transformed by concentrators into vertical vortex flows, are presented. The device allows to extend the operating range of wind speeds from 3 m/s to 60 m/s or more [8], but the transverse arrangement of the wind wheel creates resistance, as it was shown in the work [7], leading to inefficient use of the vortex energy of the flow. The reason for this may be the placement of the wind wheel across the vortex wind flow, which creates additional resistance and reduces the capacity of the structure.

Thus, the main barriers in the development of wind power are: constant pointing to the wind, high resistance of the wind wheel, cantilever tension of the blades, vibration of the blades and noise interference, high accident rate [9].

All this suggests that it is advisable to conduct a study to improve the efficiency of the vortex wind device, which will include a concentrator to create vortex motion and flow concentration on the blades of a wind wheel, a wind wheel with low resistance and a vertical pipe to improve the throughput of the device and enhance the flow movement due to vertical traction. The above problems are solved by using the vortex effect and the concentration of the flow with its direct supply to the blades of the wind wheel, creating a stable vortex motion inside the concentrator and drawing the exhaust flow through a vertical pipe mounted on the concentrator.

The development of a vortex wind device is associated with the problems of existing wind farms, which include: the presence of wind guidance mechanisms; unstable rotation of the wind wheel, the negative impact of the «trace» of the wind flow behind the wind wheel on subsequent wind farms.

These problems in [2–9] are solved by using the vortex effect and the concentration of the flow with its direct supply to the blades of the wind wheel, creating a stable vortex motion inside the concentrator and drawing the exhaust flow through a vertical pipe mounted on the concentrator. A description of the new solution is given in the patent [10]. Mathematical modeling methods and experimental studies on models were used to build a model and a semi-industrial installation. The main assumptions and input parameters of mathematical modeling are given in the article [11].

All this allows to assert that it is expedient to conduct a study on aimed at overcoming the existing problems of wind devices related to wind guidance, instability of wind wheel rotation due to wind turbulence, unregulated process of removing used wind, for the development of a new design of a vortex wind device.

3. The aim and objectives of the study

This will increase the efficiency of the wind device by eliminating inducing mechanisms, ensuring stable vortex motion inside the concentrator and stable rotation of the wind wheel, as well as rapid removal of exhaust air from the device.

To achieve this aim, the following objectives are accomplished:

– to eliminate the mechanisms of wind guidance and the creation of vortex motion, a concentrator with curved channels is used;

– in order to create a stable rotational flow movement in the concentrator, the curved channels are tangentially directed from the periphery to the vertical exhaust pipe and the blades of the wind wheel. The outlet of the channels is profiled on the blades, which maximizes the impact of the flow on the wind wheel;

– to increase the capacity of the structure, a vertical pipe is installed on top of the concentrator, which allows to increase the capacity of the device by removing the waste stream due to vertical traction.

4. Materials and methods

The object of the study is a vortex wind device. In the course of the study, methods were used that include numerical modeling and experimental studies. The applied numerical methods are known in the literature, to which references are made, including foreign ones. Similar studies are related to numerical modeling of vortex flows. The solution scheme is based on the Navier-Stokes equations, closed by empirical equations, which are selected based on laboratory experiments on certain models of the studied installations. To ensure the convergence of the solution, absolutely stable schemes are used, which corresponds to similar studies. To save machine time, iteration is used in the form of a Run-through routine, which is also well known for solving Navier-Stokes equations. Numerical methods refer to approximate solutions of the problem, so there are always certain errors in determining certain parameters, which are specified below. To clarify these parameters, laboratory experiments on experimental models and field studies were carried out.

In the course of the research, the methods of the theory of numerical methods, experimental studies on laboratory models were used (Fig. 1). Among the well-known methods of numerical simulation of three-dimensional turbulent flows, it is necessary to distinguish direct numerical simulation of turbulence and the solution of averaged Navier-Stokes equations. One of the main problems is the construction of a computational grid that takes into account geometric and physical features well. The method of modeling large vortices is a symbiosis between direct numerical modeling and the solution of averaged Navier-Stokes equations [12].

The calculation scheme is a fairly well-known technique, and it was used to calculate the parameters of a new development. Mathematical modeling of the vortex motion of the wind flow in the concentrator is a calculation algorithm with certain errors. Difficulties in determining the initial and boundary conditions are indicated in [12]. Computational experiments have shown that the velocity distribution in the concentrator depends not only on the pressure of the high-speed flow, but also on the geometric dimensions of the concentrator and the configuration of the wind wheel. The solution of these equations is accompanied by approximate numerical methods using a splitting scheme according to physical parameters. Experience shows that the accuracy of iterative operations depends on the size of the grid, i. e. on the value of the steps in time and space. An analysis of existing techniques shows that a mathematical description of turbulent flows associated with the flow of complex shapes, which also includes a vortex wind turbine with an air flow concentrator, is possible using averaged Navier-Stokes equations using the method of large vortices [13–16].

The numerical method used is a fairly flexible mathematical software that allows to adapt the calculation results to experimental data by changing the parameters in the equations of the above systems. The algorithm for solving the problem contains a subroutine based on the Run-through method. This program was used in the study of various vortex devices [17, 18]. In this case, similar studies of vortex flows based on direct modeling with the solution of averaged Navier-Stokes equations are considered. The distinctive features in the given literature are the setting of boundary and initial conditions.

The validity and reliability of scientific statements, conclusions and recommendations are confirmed by: the identification of significant processes; the accepted levels of assumptions in the mathematical description of phenomena; the validity of the assumptions arising from the basic laws of natural science and the theory of numerical methods; a sufficient number of experimental studies conducted on models of different scales.

Fig. 1 shows a laboratory experimental model of a vortex wind turbine on which the experiments were carried out. This model confirms the experiments as a research method in this section. The description of the installation is available in the patent [10].

Fig. 1. Experimental model of a vortex wind turbine

The validity and reliability of scientific statements, conclusions and recommendations are confirmed by: the identification of significant processes; the accepted levels of assumptions in the mathematical description of phenomena; the validity of the premises arising from the basic laws of natural science and the theory of numerical methods; a sufficient number of experimental studies.

5. Research results to improve the efficiency of a vortex wind turbine

5. 1. Purpose of the concentrator with curved channels

The concentrator consists of curved channels that concentrate the air flow on the blades of the wind wheel and create a stable vortex motion in the concentrator.

Computational experiments were supposed to be carried out with the unsteady movement of the wind flow, which enters the curved channel of the concentrator, gets a twist and runs into the blades of the wind wheel.

When solving such problems in practice, it is allowed to neglect changes in temperature and air density. This makes it much easier to solve such problems. The wind speed was chosen 5 m/s as the average wind speed in our region – the Akmola region of Republic of Kazakhstan. On the territory of Kazakhstan, the average speed of the wind flow at a height of 10 meters is 4–7 m/s. Therefore, in this case, let's neglect changes in temperature and air density. Despite the non-constant wind flow, the calculation was carried out at a constant speed value of 5 m/s, the Reynolds number was assumed to be Re=10000, to simplify the design scheme, the initial velocity field was set along the entire plane of the inlet of the concentrator channel. The geometric dimensions of the studied structure are shown in Fig. 2, where the flow diagram is given.

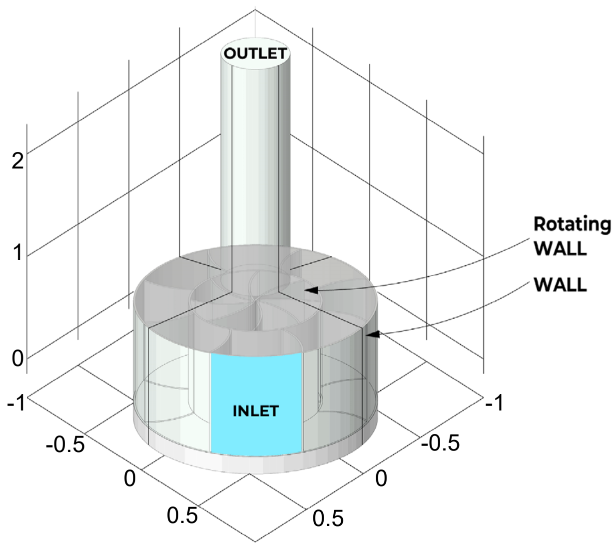

Fig. 2. Three-dimensional image of a vortex wind device

The calculation results showed an uneven velocity distribution in the curved channel of the concentrator. Fig. 3 shows the change in the contour of the air flow velocity along the wall of the concentrator channel at the time of flow stabilization. According to research, the flow in the channel stabilizes when t=0.038 c is reached and the flow pattern does not change in the future. The concentration of the flow causes its turbulence on a solid surface and an increase in the velocity at the outlet of the concentrator channel.

Calculations when air is supplied to two channels of the concentrator show an increase in the velocity of the air flow at the outlet by 10–12 times than when air is supplied through one channel. The flow becomes stationary after 20 seconds. It is assumed that the initial velocity field is uniform and strictly of the same direction. Getting into the channels of the concentrator, the air flow was directed tangentially to the inner surface of the concentrator. This ensures the vortex movement of air inside the concentrator. Steady rotational motion creates a favorable mode for the operation of the wind wheel.

Numerical simulation of the movement of air flow in a wind turbine has shown the effectiveness of using concentrators in wind devices. The numerical experiment makes it possible to determine technologically simple and cheap variants of concentrator designs, as well as to increase the efficiency of wind power by reducing the material consumption of the structure.

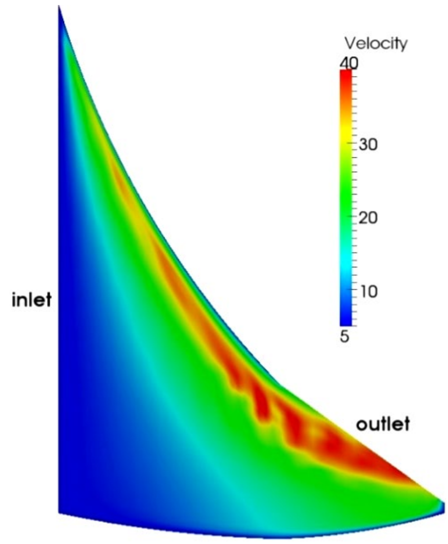

Fig. 3. Velocity profile in the concentrator channel at an incoming flow velocity of 5 m/s and time t=0.038 s

5. 2. Ensuring stable vortex motion inside the concentrator

For maximum energy transfer of the vortex flow, the curved channels are tangentially directed from the periphery to the vertical exhaust pipe and the blades of the wind wheel in such a way that the outlet opening of the channels is profiled on the blades, which maximizes the impact of the flow on the wind wheel.

The program used the flow parameters at the outlet of the concentrator channels to determine the velocity profile inside the concentrator. Visualization of the vortex turbulent flow motion in a vortex six-channel wind turbine is shown in Fig. 4, which shows the dynamics of the airflow in the concentrator in the form of isolines and isosurfaces. These data are obtained from the assumption that the wind is directed from one side and air enters the structure through two concentrator channels.

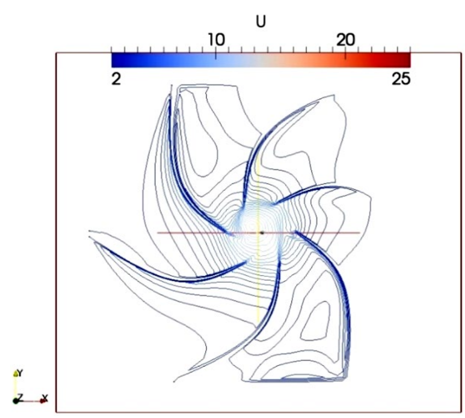

Fig. 4. Velocity isolines inside the concentrator at a time step of 20 s

Laboratory experiments on the models were carried out using several variants of wind turbines with different wind wheels (Fig. 5).

In view of the fact that the attachment of the blades of the wind wheel to the shaft or to the rotating cylinder led to undesirable results, which made it possible to choose the optimal configuration of the wind wheel according to the results of experiments – option *f*.

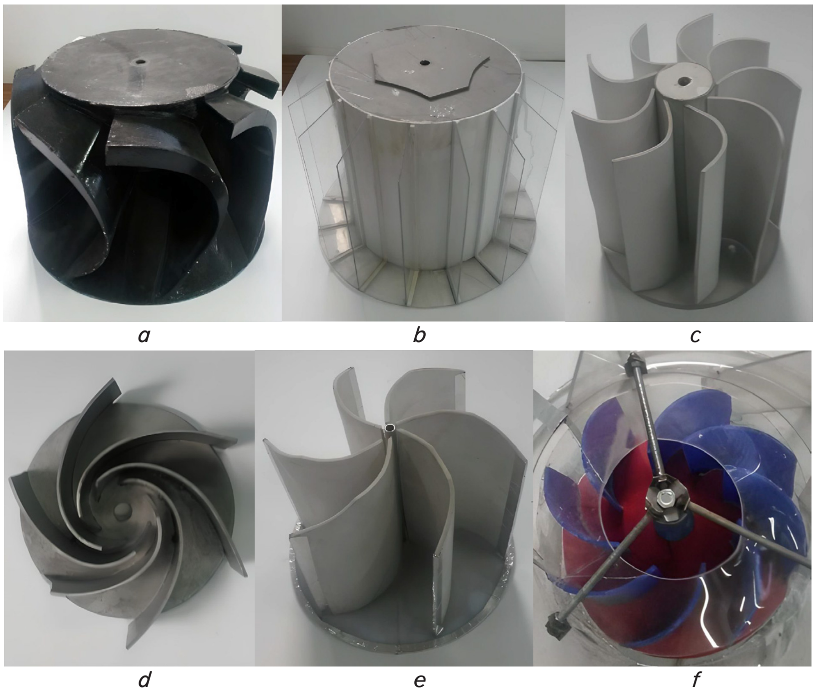

Fig. 5. Variants of the wind wheel:
a – vertically curved blades on the axis; *b* – rectilinear blades on a wide cylinder; *c* – curved blades on a narrow cylinder; *d* – without axial blades; *e* – horizontally curved blades on the axis; *f* – curved blades on a cone

Fig. 7 shows the effect of air consumption on the rotation of the wind wheel and the use of a vertical pipe for exhaust air removal. Field observations for the period 2017–2019 showed a good match with the calculated and experimental data. During this period, the vortex wind device operated in a stable mode with sudden changes in the directions and values of the wind flow velocity. This once again proves the effectiveness of this design in comparison with existing wind farms.

As the main characteristic of wind turbines is the determination of the dependence of the rotation of the wind wheel on the magnitude of the wind flow velocity under different modes (Fig. 7). Mode one – air supply to one channel of the concentrator. Mode two – air supply to the two channels of the concentrator. The third mode is also connected with the supply of air to the two channels of the concentrator, but without a vertical pipe for exhaust air. The graphs show that the rotation of the wind wheel is affected by the air supply through the channels and the presence of an exhaust pipe. When the air flow enters one channel (mode 1), the wind wheel revolutions are less than when using two channels (mode 3). A decrease in speed also occurs in the absence of a discharge pipe (mode 2).

5. 3. Increasing the capacity of the turbine by removing the exhaust flow using the exhaust pipe

To effectively remove the waste stream, a vertical pipe is installed on top of the concentrator, which increases the speed of the vortex flow due to vertical thrust. Increasing the flow rate in the pipe increases the throughput of the vortex wind device.

Laboratory experiments were carried out on wind turbine models (Fig. 1, 6). The geometric dimensions of the experimental models were determined by calculation. The models were used to measure the velocity distribution in the cross sections of the curved channels of the concentrator, as well as in the discharge pipe. Experimental measurements have shown that the experimental data qualitatively coincide with the calculated velocity distributions. Such a coincidence of the calculated and experimental data shows the adequacy of the chosen computational model and the use of approximation polynomials.

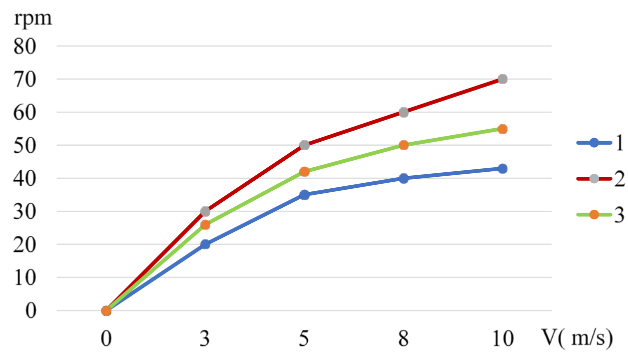

Fig. 7. The dependence of the wind wheel speed on the wind speed in different modes: 1 – mode 1; 2 – mode 2; 3 – mode 3

Fig. 6. Experimental model of a vortex wind turbine

The positive results of the research of the vortex wind device led to the creation of a semi-industrial sample, which participated in the competition for demonstration in the Kazakhstan pavilion «Sphere» of the international exhibition EXPO-2017.

A semi-industrial installation of a vortex wind turbine was placed in the industrial zone of Astana (Fig. 8) to demonstrate and identify possible errors in the design of the product. During its operation (from 2017 to 2019), the vortex wind farm proved to be a reliable and safe object. There was no noise interference, vibration of the blades, ice formations and snow drifts. On January 11, 2018, a strong blizzard passed in Astana, the wind speed reached up to 51 m/s. Despite the fact that the wind tore roofs off houses, knocked down construction cranes, the vortex wind turbine was working normally, not a single node of the structure was damaged.

Laboratory and field studies have shown that the concentrator fulfills its task – it ensures the concentration of the flow on the blades of the wind wheel and creates a vortex movement inside itself. The vortex motion of the flow in the concentrator ensures a stable and uniform movement of the wind wheel. The vertical pipe to the concentrator provides exhaust air removal and increases the speed of the vortex flow inside the pipe, thereby increasing the throughput of the entire structure.

Fig. 8. Semi-industrial installation of a vortex wind turbine

The result of the research is the development of a vortex wind device. Calculations and experiments are used as auxiliary elements, which are tools for determining and identifying the parameters of a new development. Therefore, as the main result, the design of a vortex wind device and its working body – a wind wheel are presented. As auxiliary results, the data of calculations and experiments confirming three factors are presented: a concentrator with curved channels perceives the wind flow from all sides, while there is no need to turn it to the wind; a vortex motion is created inside the concentrator; a vertical pipe increases the productivity of the installation due to traction and thereby increases its efficiency.

6. Discussion of the results of studies of the efficiency of a vortex wind turbine

As noted above, the first task was related to the problem of wind guidance mechanisms at operating wind farms. Similar studies are related to the use of different walls to concentrate the flow on the blades of the wind wheel. But this did not lead to a regulated flow. In this connection, let's propose to use a concentrator with curved channels, the scheme of which is shown in Fig. 2. Unlike rectilinear walls, the curved channels we offer allow to concentrate the wind flow on the blades of the wind wheel and provide a tangential entrance to the concentrator. This is confirmed by our calculations and experiments (Fig. 3). On the other hand, mathematical modeling of vortex motion [9, 17, 18] also confirms the provision of a stable rotational flow. In contrast to [17], where stationary rotational motion is considered, in our case let's use a change in parameters over time to ensure the stability of the design scheme and determine the time of stabilization of the vortex flow. Such a result – vortex motion due to the concentrator with curved channels allows to completely eliminate the use of wind-inducing mechanisms. This is possible thanks to the curved channels located around the concentrator.

Computational experiments were supposed to be carried out with the unsteady movement of the wind flow, which enters the curved channel of the concentrator, gets a twist and bumps into the blades of the wind wheel. Let's neglect changes in air temperature and density. Despite the unstable wind flow, the calculation was carried out at a constant speed of 5 m/s, the Reynolds number was assumed to be Re=10000, to simplify the design scheme, the initial velocity field was set along the entire plane of the inlet of the concentrator channel.

The second task is related to ensuring stable vortex motion in the concentrator. Studies by other authors [19, 20] confirm the steady vortex motion created by the guide vanes. The effect on the vortex wake in a turbulent flow is considered in [21] with the help of guide walls. The use of guide walls for twisting the flow allows to create a stable and controlled air movement in special devices. The use of guide vanes has been studied by the German company Turbina Energy AG [21]. In contrast to [19–21], where the possibility of creating a stable rotational motion is studied, in our case let's consider the concentration of wind flow on the curved blades of the wind wheel. This result is the direction of the flow tangentially from the periphery to the vertical discharge pipe and the blades of the wind wheel, so that the outlet openings of the channels are profiled on the blades, allowing the flow to affect the wind wheel as much as possible. This is possible due to the stable rotational movement of the wind flow inside the concentrator. This fact is confirmed by the calculated data on the speed distribution in the concentrator (Fig. 4).

The third task is to increase the capacity of the wind device due to the vertical pipe installed on the concentrator, provided by vertical traction. Similar works are related to the study of the solar vortex structure [22], which was developed at the Georgia Institute of Technology (Atlanta, USA). In russia, wind devices were created using the Darye rotor in the form of various modifications [23]. In these works, the problem of the throughput of the vortex device was not considered, the resistance of the concentrator was not studied. To solve this problem, let's use a vertical pipe, which allowed to provide a solution to the third problem. This result is an increase in the throughput of the vortex wind device, which makes it possible to increase the efficiency of the wind turbine. This is possible due to the vertical thrust formed by the pipe installed on the concentrator. Experimental studies of the effect of a vertical pipe on the rotation speed of a wind wheel are shown in Fig. 7, which shows the effect of a vertical pipe on the throughput of the device.

The efficiency of the wind turbine is also affected by the configuration of the wind wheel. The problem of optimizing the profiles of the wind wheel blades is confirmed by the data of other researchers [24]. It should be noted that in all studies related to the development of wind energy, the red line is not only the reduction of the carbon footprint, but also the impact of wind power plants on ecology, the environment [25]. As our research has shown, the proposed development eliminates the above problems of existing wind turbines. An important point of this study is the achievement of the set goals and the creation of a new design of a vortex wind device.

The proposed development passed three rounds of the competition and was selected for demonstration in the Republic of Kazakhstan pavilion at the international exhibition EXPO-2017. In order for interested persons to see this structure «live», a semi-industrial sample was built on the instructions of the Ministry of Energy of Kazakhstan, which was installed in the industrial zone of Astana (Fig. 8).

As a practical use of the proposed innovation, an interesting fact can be cited – in 2018, on January 11, a storm occurred in Astana, the wind speed reached up to 51 m/s. The wind tore roofs off houses, construction cranes fell, many wind farms failed. And in this situation, the proposed development worked in a stable mode. The advantage of the innovation is the ability of the device to operate at high speeds at which existing wind farms cannot operate.

In the analysis, much attention is paid to the study of the mathematical model and the application of numerical methods for the study of a vortex wind device. As it is known, any mathematical model has its own error, which is reflected in the results obtained. To improve the optimization of design parameters, more accurate mathematical models are needed. Nevertheless, this work is not devoted to the possibilities and problems of mathematical modeling of vortex flows. This is not the purpose of these studies.

An important point of our research is the possibility of using a vortex wind turbine in a populated area, placing it on the roofs of a building or industrial zones. As field experiments have shown, the wind device has no noise interference, it is safe for people, birds, insects and animals. In the future, let's plan to investigate the operation of our wind turbine together with a direct-flow hydro turbine. Such an alliance will eliminate the use of batteries for energy storage. The integrated use of various renewable sources is one of the important directions in the energy sector.

The limitation of these studies is the materials for the manufacture of the proposed design. A concentrator with curved blades and a vertical pipe can be made of concrete or metal, and a wind wheel can consist of combined materials that facilitate its design and long-term operation. Not only the reliability of the wind turbine, but also its effective operation will depend on the materials used.

As a future work, let's plan to conduct a study to determine the parameters of curved channels, study the profiles of the blades of the wind wheel, the possibility of using twisting devices in a vertical pipe.

7. Conclusions

1. The use of a concentrator with curved channels completely eliminates wind guidance mechanisms. The concentrator allows to increase the speed of the wind flow by 1.5 times. A vortex motion is created inside the concentrator, which acts uniformly on all the blades of the wind wheel at the same time.

2. Thanks to the curved channels of the concentrator, a stable rotational flow is created inside it, which simultaneously creates positive pressure on the surfaces of the curved blades and does not affect the reverse sides, thereby creating an optimal mode of wind flow action on the blades of the wind wheel.

3. To increase the throughput of the vortex wind device, a vertical pipe is installed on top of the concentrator, which creates additional thrust and increases the speed of the exhaust flow. The external air flow, entering the curved channels of the concentrator, increases the speed and tangentially enters the concentrator. A stable vortex motion is formed inside the concentrator, which acts uniformly on all the blades of the wind wheel. The swirling flow is removed from the concentrator through a vertical pipe due to vertical thrust.

Conflict of interest

The authors declare that they have no conflict of interest in connection with this research, whether financial, personal, authorial or otherwise, which could affect the research and its results presented in this scientific article.

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Data availability

Manuscript has no associated data.

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