ANNOTATION

Dissertations for the degree of Doctor of Philosophy (PhD)
in the educational program
8D05303-Thermophysics and theoretical heat engineering

TLEUBERGENOVA AKMARAL ZHARYLKHASYNKYZY

Investigation of the influence of thermophysical parameters of the air flow on the aerodynamics of combined blades of a wind power plant

Topic relevance. Mankind has always been interested in alternative energy sources in the world, especially recently. In addition to providing the regions with electricity, the development of renewable energy sources is necessary to save fuel and energy resources and reduce the negative impact on the environment.

Today, wind energy is actively developing, one of the tasks of which is to develop wind energy capable of operating efficiently even at low wind speeds.

For the development and creation of wind power plants (wind turbines) with an average annual wind speed of less than 6 m/s for most of the territory of Kazakhstan, it is necessary to search for new technical solutions that ensure the energy efficiency of wind turbines with frequent changes in the air flow velocity with a polytropic wind rose, including their low cost and small weight and size parameters.

Therefore, the development of a wind turbine with combined blades operating at low wind speeds, the study of aerodynamic characteristics presented in the thesis, is relevant. That is, a horizontal axis wind turbine operating at low wind speeds, developed as part of this research work, has a number of advantages: it can start generating energy at low speeds, they can be installed in many places, compared to traditional horizontal wind turbines, many of which are much quieter and have less vibration, which makes them more suitable for installation near residential areas. The ability to operate at low wind speeds allows them to be installed in areas where larger generators are inefficient, increasing the overall potential of wind power.

The purpose of the dissertation research is influence of thermophysical parameters of the air flow on the aerodynamics of combined blades of a wind power plant.

To achieve the goal, the following tasks were set:

1. An analytical review of research on the aerodynamics of wind power plants with different blade geometries and different rotation axis orientations.

2. Numerical simulation of the aerodynamics of a wind turbine with combined blades using the Ansys Fluent software.

3. Design (development) and creation of a laboratory model of a wind power plant with combined blades.

4. Conducting test measurements of the aerodynamic characteristics of a laboratory model of a wind turbine with combined blades under various flow conditions.

5. Comparative analysis of the results of numerical calculations and experimental data on the study of aerodynamic characteristics of a wind power plant model with combined blades;

6. Investigation of the influence of thermophysical parameters of the air flow on the aerodynamics of combined blades of a wind power plant.

The object of the study is the aerodynamics of a laboratory model of a combined wind power plant with a horizontal axis of rotation.

Research methods. Experimental studies in the working part of a wind tunnel, allowing measurements of the values of lifting force, drag force and traction force of a wind power plant model when the air flow velocity and angle of attack change. Numerical simulation of the aerodynamics of combined blades of a wind power plant using the ANSYS FLUENT software.

The scientific novelty consists of the following:

1. For the first time, a mathematical model has been constructed and an experimental sample of a combined wind power plant consisting of a fixed blade and a rotating cylinder has been developed. The engine starts working at a wind speed of 3 m/s.

2. The thrust force of the optimal wind turbine when the fixed blade was positioned at an angle of 30 degrees relative to the cylinder was 2.9 N. It was found that a three-bladed wind turbine has a higher thrust than a two-bladed one. The values of the aerodynamic forces acting on the wind turbine are determined: a lifting force of 3.55 N and a drag force of 6.25 N.

3. The number of revolutions of the composite blade at N = 637 rpm, the pressure value at a height of 1 mm is P = 0.22 Pa, and at a height of 7 mm-P = 0.44 Pa. It is established that the pressure in the air flow above the cylinder is at a minimum value.

4. It has been established that with an increase in the values of the thermophysical parameters of the air flow, such as t temperature, μ dynamic viscosity, v kinematic viscosity, λ coefficient of thermal conductivity, C_P coefficient of heat capacity, the traction force of the wind turbine increases.

5. It was found that for a wind turbine with a wind wheel with a diameter of 1.8 m and cylinders with a diameter of 150 mm, 0.69 m long, rotating at a frequency of 300 rpm, the electric generator begins to generate electricity at a wind speed of 3 m/s, while the speed of rotation of the wind wheel is 50 rpm.

The main provisions submitted for defense:

1. In the course of mathematical modeling, the combined blade at air flow velocities from 3 m/s to 15 m/s in the range of the angle of orientation of the fixed blade ($0° \leq \alpha \leq 60°$) reduces drag by 7% at an angle of 30 degrees, which is due to an increase in lifting force.

2. The formation of velocity and pressure fields in the turbulence mode around the wind turbine of the installation in the range of Reynolds numbers from 1×10^4 to 5×104, led to the achievement of optimal values of the drag coefficient from 0.20 to 0.26 and a change in the lift coefficient from 0.41 to 0.14.

3. Testing of the developed monitoring system for a prototype wind power plant showed that when the air temperature changed in the range from -25° C to +25°C when using a fixed blade with an orientation angle of 30 degrees, the thrust force increased up to 1.8 times.

The relationship of the work with the plan of the state scientific programs. AP23483857 "Development and creation of a new design of a prototype wind power plant with a complex geometric shape of the blades".

Approbation of work results. The main results of the dissertation were reported and discussed at the following conferences: «Fundamental and applied science: state and development trends» Collection of articles of the XV International Scientific and Practical Conference (Petrozavodsk, November 8, 2021), In the materials of the 12th International Scientific Conference «Chaos and structures in nonlinear systems theory and practice» (Pavlodar, June 17-19, 2022), Modern scientific research: collection of articles of the International Scientific and Practical Conference (Penza, 2022), At the international scientific and practical conference «Shokan readings-26: vectors of development of Kazakhstan's Science in the context of interaction with the region», dedicated to the 60th anniversary of Kokshetau university named after sh. Ualikhanov (Kokshetau, 2022), Seventh International Scientific Conference. Alternative energy sources, materials and technologies. AESMT'24. (Sofia, Bulgaria, 14 - 15 May 2024).

Publications. 27 papers have been published on the topic of the dissertation, including 3 papers in publications included in the Web of Science or Scopus database, 8 papers in publications from the list approved by the Committee for Control in Education and Science of the EOM of the Republic of Kazakhstan, 10 papers in publications included in collections of materials from international conferences, 1 work in the publication included in the collections of materials of Republican scientific and practical conferences, 2 works in the publications included in the RSCI database, 1 work in the Republican Journal and 1 monograph.

In particular, the patent for the utility model «Horizontal-axial wind power plant with combined blades» No. 9072 dated 14.02.24 was obtained in collaboration.

Scientific and practical significance of the work lies in the development of a combined bladed wind power plant with a horizontal axis of rotation containing cylinders rotating around their axes and blades fixed relative to the axes of the cylinders, which has high efficiency. The results of experimental studies obtained on a combined-blade wind turbine can be used in the development of a specific wind turbine model for power supply to remote consumers and facilities from centralized power supply systems.

Personal contribution of the author. The author has carried out work on the design and creation of a combined bladed wind power plant with rotating cylinders and blades fixed relative to the axes of the cylinders. The author was directly involved in the development of a laboratory and prototype wind power plant. Laboratory and field experiments were conducted. The analysis of the obtained quantitative and experimental results of the study was carried out jointly with scientific consultants. The writing of the published papers was carried out by the joint efforts of the co-authors with the direct participation of the dissertation director.

The structure and scope of the dissertation. The structure of the dissertation work is determined by the tasks, the solution of which is necessary to achieve the purpose of the dissertation. The dissertation consists of an introduction, 6 sections, conclusions, a list of used sources from 120 titles and contains 135 pages of typewritten text. The work is illustrated with 152 figures and includes 5 tables.