ANNOTATION

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

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Investigation of aerodynamic parameters of a wind power plant with a complex geometric shape of blades

Topic relevance. The main activity of the renewable energy sector is the use of wind and solar energy. Kazakhstan has a rich wind potential, about 50% of the country's territory has an average wind speed of 4-5 m/s at an altitude of 30 m. According to UN estimates, Kazakhstan's wind potential is 1.8 trillion kWh per year, which is almost 10 times higher than the current energy consumption in Kazakhstan.

Based on the research conducted within the framework of the joint work of the Ministry of Energy and Mineral Resources of the Republic of Kazakhstan and the United Nations Development Program, it can be argued that Kazakhstan is dominated by territories with ideal wind conditions for the construction of wind power facilities and systems . According to the results of the study, wind flows with a speed of more than 7 m/s are observed on an area of more than 50,000 km^2, at an altitude of 80 meters. And in some areas at an altitude of 15 meters, winds with a speed of 27-36 meters per second were recorded. In the predominant part of Kazakhstan, which accounts for more than 50% of its total territory, the wind speed of about 3.5-5 m/s provides a huge wind potential of the country.

It is known that traditional bladed wind power plants are ineffective at small ranges of wind speeds. Wind power plants with blades in the form of rotating cylinders operating on the basis of the Magnus effect have been developed for areas rich in low-speed winds. However, such wind power plants also have their drawback in the form of electric drives.

In this regard, an urgent task is the development and research of wind power plants with a complex geometric shape of the blades, with the exception of an electric drive for the promotion of the blades.

The purpose of the dissertation research is numerical modeling and experimental study of the aerodynamic parameters of a wind power plant with a complex geometric shape of the blades.

The objects of research are experimental and experimental samples of wind power plants with a complex geometric shape of the blades.

The scientific novelty consists of the following:

1. For the first time, a mathematical model of a wind power plant with a complex geometric shape of the blades operating on the basis of the Magnus effect and Bernoulli's law was developed and created. The Realizable k-ε turbulence model was used for numerical simulation.

2. The results of three-dimensional numerical modeling (pressure distribution fields and velocity vectors) of a wind power plant with two and three blades and the blade itself, conducted in the Ansys Fluent program, are obtained. The nature of the turbulent vortex flow around a rotating cylinder with a deflector is explained.

3. For the first time, an experimental comparative analysis was carried out in order to determine the most effective material for a rotary deflector element, during which it was found that a blade with a metal deflector has better aerodynamic parameters compared to a blade with a plastic deflector.

4. Based on optimized numerical simulation data, a mock-up of an experimental installation with two and three cylindrical blades with a deflector was created.

5. Comparative dependences of the aerodynamic forces of the wind power plant layout on the air flow velocity, as well as their coefficients on the Reynolds number obtained by numerical and experimental methods, are established. Comparison of experimental and numerical data shows a satisfactory correspondence, where the proof is a high value of the approximation confidence value $0.95<R^2<0.99$.

6. For the first time on the basis of a mathematical model, a prototype wind power plant with a complex geometric shape of the blades was developed and created. Experimental and climatic tests were carried out, followed by a study of the effect of air temperature on the thrust force of the wind turbine.

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, 5 sections, conclusions, a list of used sources from 136 titles and contains 145 pages of typewritten text. The work is illustrated with 123 figures and includes 13 tables.

The main results include the following:

1. Computational model and results of numerical simulation of the flow around a wind power plant with cylindrical blades, unwinding due to the use of active deflectors, the use of which makes it possible to exclude the use of external forces for their unwinding.

2. The results of experimental studies confirming the properties and capabilities of the developed means of all-mode modeling of a wind power plant with a complex geometric shape of the blades in real time and at an unlimited interval.

3. The method of measuring the aerodynamic characteristics of a prototype wind power plant with a complex geometric shape of blades with a horizontal axis of rotation allows to adequately determine its parameters in various climatic conditions, taking into account the thermophysical parameters of the air varying from temperature.

Scientific and practical significance of the work:

1. Mathematical modeling of a cylindrical blade with a deflector and the wind power plant itself with two and three blades in the Ansys Fluent program, with the numerical results obtained, can be used in various numerical problems of aerodynamics, physics, thermophysics and energy.

2. Experimental data on testing laboratory models of cylindrical blades with a deflector and wind power plants with two and three blades, with the obtained experimental results of aerodynamic parameters depending on the flow mode, can be used in the development of wind turbines with the exception of an electric drive for the promotion of cylindrical blades, as well as in understanding the aerodynamics of power elements of wind turbines with a complex geometric shape.

3. The method of measuring the aerodynamic characteristics of a prototype wind power plant with a complex geometric shape of blades with a horizontal axis of rotation, allows you to adequately determine its parameters in various climatic conditions.

Approbation of the work and publications. The main results of the dissertation work were reported and discussed at: V International Scientific and Practical Conference "Science and technology innovations" (Petrozavodsk, December 13, 2020); XVII International Scientific and Practical Conference "Modern Science: current issues, achievements and innovations" (Penza, November 5, 2021); XII International Scientific and Practical Conference "Fundamental and Applied Science: state and development trends" (Petrozavodsk, June 7, 2021); International Scientific and practical Conference "Science of Kazakhstan for the years of Independence. Achievements and Prospects of development dedicated to the 30th anniversary of Independence of the Republic of Kazakhstan" (Kokshetau, April 21, 2021); IV International Scientific and Practical online Conference "Energy and resource-saving technologies: experiences and prospects" (Kyzylorda, March 30, 2022); II International Scientific and Practical Conference "Development of Modern science: experience, problems, forecasts" (Petrozavodsk, October 24, 2022); Republican scientific and practical online conference "Actual problems of modern Physics and semantic pedagogy" (Karaganda, May 13-15, 2021); XII International Scientific Conference "Chaos and Structures in nonlinear systems. Theory and Experiment" (Pavlodar, 2022).

Publications. 23 works have been published on the topic of the dissertation, including 4 works in publications included in the Web of Science or Scopus database, 4 works in publications from the list approved by the Committee for

Control in the Field of Education and Science of the Ministry of Education and Science of the Republic of Kazakhstan, 8 works in publications included in the collections of materials of international conferences, 1 work in the publication included in collections of materials of Republican scientific and practical conferences, 3 works in publications included in the RSCI database, 1 work in a Republican journal and 1 textbook.

In particular, a patent for a utility model "Blade in the form of rotating cylinders with an active deflector" No. 6632 dated 05.11.2021 was obtained in co-authorship.