

SOME DESIGN FEATURES OF THE CAROUSEL TYPE WIND TURBINE BIDARRIEUS

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The article presents the results of studies to improve the vertical-axis Darrieus type wind turbine with two coaxially located rotating shafts. Some design features of the symmetrical NACA-0021 airfoil are discussed. Both moving blades streamlined area scheme is shown. The brief description of the laboratory models of the carousel type wind turbine with HBI-rotor is given. It is shown that placement of a vertical-axis wind turbine at a certain height, above the surface boundary layer, can provide opportunities to further improve its effectiveness.

Keywords: wind turbine, NACA airfoil, Darrieus, Bidarrieus, HBI-rotor, surface boundary layer

Introduction

At present in economically developed and developing countries promising is the use of local renewable energy sources. In many countries, wind power has become the backbone of their strategies for phasing out fossil and nuclear energy. According to the official statistical report World Wind Energy Association on June 4, 2019 the total capacity of all wind turbines installed worldwide by the end of 2018 reached 597 Gigawatt [1, 2]. Now all wind turbines installed by end of 2018 can cover close to 6% of the global electricity demand.

The Republic of Kazakhstan is one of the richest countries of the world in terms of renewable resources, evaluated to over 1000 billion kWh/year [3-5]. Now in Kazakhstan the use of wind energy is significant increases because it is most affordable and relatively cheap in implementation. The relevance and need of the development of wind energy is due to also the fact that Kazakhstan has voluntary commitments to reduce greenhouse gas emissions on 15% by 2020 and on 25% by 2050. It is also due to the worn-out equipment of existing thermal power plants and to large volume of their harmful emissions into the atmosphere.

For the successful development of wind energy the government support and thorough study of the potential of wind energy are required. Research in this direction using modern technology is still relevant [3]. In general, according to experts, the potential for wind energy, which can be realized, is 10 times higher than in Kazakhstan's electricity demand. Nevertheless, until now, the total capacity of all existing wind farms in Kazakhstan is only 1% of the total electricity generation. This is due to several reasons, one of which is the low efficiency of existing wind plants.

Despite the wide variety of operating wind turbines of various manufacturers and well-known companies, the creation of highly efficient wind power units (WPU) operating in a wide range of wind speeds remains an urgent problem. This problem can be solved by developing methods for improving existing wind turbines. A basic design of HBI-rotor and an operation principle of the Bidarrieus-2 wind turbine were discussed [6-8]. Let's consider some design features of this carousel type wind turbine.

1. The symmetrical NACA – 0021 airfoil

Now the propeller-type wind turbines with installed capacity up to several megawatts are widely used. On the basis of many years of experience, the technology of creating a high-power WPU of a propeller-type wind turbine has been mastered [8, 9]. But practice shows that the higher the capacity of wind farms, the wider the lifeless territory in these regions (birds, fauna, including the population, leave these places). Also, the gyroscopic effect of a propeller wind turbine can lead to emergency situations [9]. More preferable are the carousel type Darrieus wind turbines, which have the symmetrical wing form NACA and operate on the lifting power of the blades [6, 9-13].

The overall dimensions of such devices are much less at the same values of the installed power. The material consumption and space occupied by these devices is much less than the propeller ones. At the wind turbine Darrieus the flow is uninterrupted, and as a result, its work is almost noiseless. Darrieus apparatus has the advantages over propeller wind turbines, because a symmetrical airfoil of NACA provide continuous flow of operating blades with wind stream and so the turbulence level of wind turbine decreases, Fig.1.

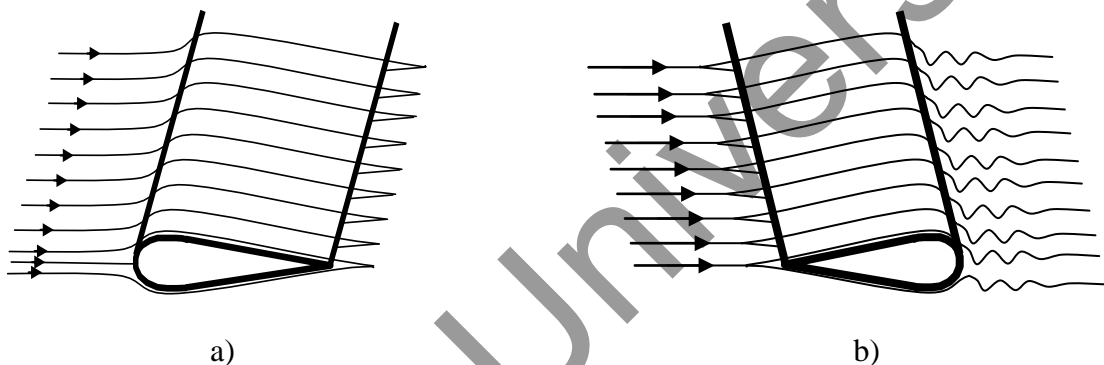


Fig.1. The flow pattern of the symmetrical NACA – 0021 airfoil: a) - continuously under frontal direction of the wind flow; b) - tear-off flow under wind flow from blade tail side

The drag force of the NACA-0021 airfoil ξ_{xf} under $\varphi = 0$ (Fig.1a) is small and equals:

$$\xi_{xf} = C_{xf} \rho \frac{U^2}{2},$$

where $C_{xf} = 0.0028$ is the drag coefficient.

Resistance of the same profile NACA-0021 to the wind flow directed to its trailing edge (turned towards) is an order of magnitude higher due to the separation flow (Fig. 1b):

$$\xi_{xb} = C_{xb} \rho \frac{U^2}{2},$$

where $C_{xb} = 0.16$.

According to previous static wind tunnel measurements of different tubercle configurations, the validation test for the optimum combination of and for NACA0021 was performed on an H-Darrieus wind turbine at various Reynolds numbers [11]. It was demonstrated experimentally that this blade could significantly increase the turbine self-starting capability at the expense of slightly lower peak power output, which was consistent with the numerical studies performed in [12].

These blades are very promising candidates for the future application in the low wind environment. Researchers continue to investigate blade profiles to Darrieus type wind turbine application [10, 11], but the results remain in conclusive and sometimes conflicting. The traditional symmetrical NACA series with large thickness still presents a simple but effective choice of blade geometry achieving a good compromise between good starting performance and adequate peak power operation.

Schematically streamlined areas of the blades are shown in Figure 2. It can be seen that the total streamlined area is obtained is almost 2 times larger than in a conventional Darrieus wind turbine. As a result, the amount of wind energy used by wind turbines with an HBI rotor should increase by 2 times [6, 7, 13].

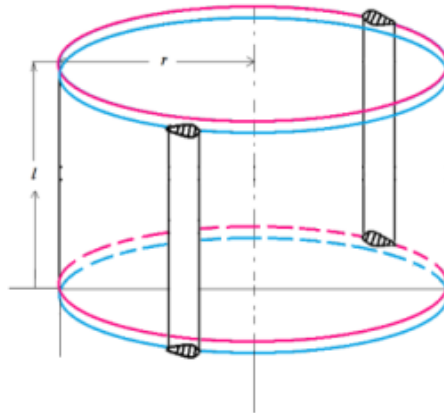


Fig. 2. Scheme streamlined areas of both working blades of the HBI rotor.

2. Testing models of the wind turbine HBI-rotor

A working laboratory and experimental version of the 5 kW kW HBI rotor wind turbine was designed and manufactured by research team of professor Sh.A. Yershin (photo in Fig. 3 a,b). Bidarrieus wind turbines with HBI rotor has two diametrically opposed blades, which are NACA wing profiles symmetrical with respect to the chord.



a)



b)

Fig.3. Active laboratory model of wind turbines HBI-rotor:

a) main view; b) its location in the working section of the wind tunnel.

The experimental version of the Bidarrieus wind turbine of the HBI rotor has next dimensions: diameter of the wind turbine - 4 m, height - 5 m. Symmetrical blades NACA-0021, 2 m long and a chord of 0.5 m were used. The central shaft is connected by a half-span with one blade, the outer shaft with a half-span with the second blade which are located at an angle of 180° to each other. This position is determined using a special lock. The autonomy of the rotation of the shafts is provided by ball bearings separating them. An energy generator allows you to increase the total energy, get equipment. The energy generated by the two electric generators is summed up than usual [14, 15].

Tests of the developed semi-industrial Bidarrieus wind turbine with a 5 kW HBI-rotor showed the need for its placement at a certain height [15]. The fact is, outside the surface boundary layer where wind speeds are 2-2.5 times higher than the average wind speed in the surface boundary layer. Due to the cubic dependence of the wind turbine power on wind speed, the location of the wind turbine outside the surface boundary layer (20-30 m) will lead to a several-fold increase in the power of the wind turbine.

Therefore, the wind turbine should be installed at a height of 30 meters with the help of a light tripod above the surface boundary layer (Fig. 4). The tripod (1) is assembled from several I-beams, and for the strength of the structure, the tripod is fastened with several hoops (2).

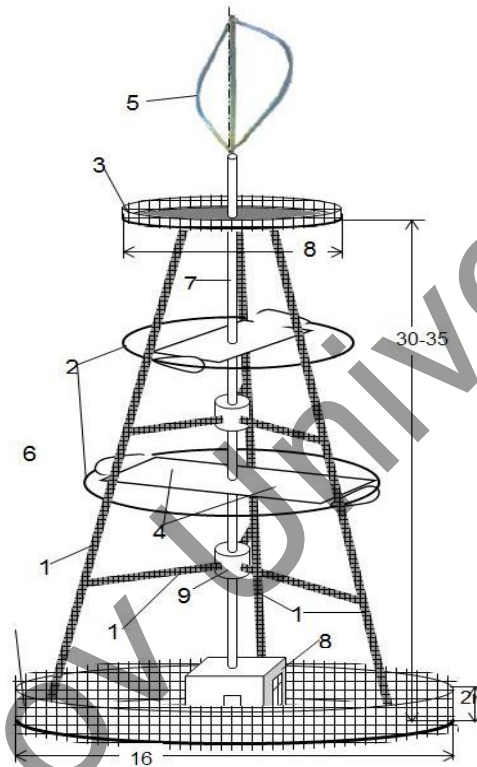


Fig. 4. Wind turbine with a vertical axis of rotation of the troposkino system (Darrieus with curved blades):

- 1 - tripod, 2 - hoops, 3 - mounting pad, 4 - NACA horizontal wing blades for stranding the wind turbines, 5 - wind turbines, 6 - guards for installation and batteries, 7 - rotation shaft, 8 – block for electric generator and batteries, 9 – bearings

Thus, there is reason to believe that the proposed option of a wind turbine with a capacity of 5kW will allow obtain an output power of up to 40-50 kW. At the same time, the economic performance of the construction is unlikely to affect the cost of the device. Unfortunately, due to force majeure circumstances, it has not yet been possible to conduct laboratory and field tests of these units.

Despite its geometrical simplicity, the aerodynamics of the Darrieus type wind turbine is complicated involving highly unsteady flow passing through its rotor [12]. The unsteadiness is caused mainly by the large variations of the blade angle of attack during the rotor operation. High rotor solidity (turbines with more than two blades) additionally contributes to the unsteadiness of the flow passing through the turbine by increasing the angle of attack fluctuations [14]. Wind turbines should provide stability for the extraction of wind energy. The use of brake pads, which automatically regulate the rotation of the shaft, up to its complete stop at drilling wind speeds, is supposed.

Conclusion

The vertical axis carousel type wind turbine Bidarrius with HBI-rotor is one of the most promising wind energy converters for locations where there are rapid variations of wind direction, such as in the built environment. The most challenging considerations when employing one of these usually small machines are to ensure that they self-start and to maintain and improve their efficiency. However, due to the turbine's rotation about a vertical axis, the aerodynamics of the turbine are more complex than a comparable horizontal axis wind turbine and our knowledge and understanding of these turbines falls remains far from complete.

This carousel type two-rotor wind turbine Bidarrius-2 has a low rotation speed. This allows it to work at high velocities of wind and the operating terms will not be limited practically. All this makes it important and necessary to carry out full-scale tests of these WPU's in order to ensure their industrial production in the future.

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