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MOBILE COMPOSITE WIND POWER PLANT WITH DIFFUSER

Abstract. This research focuses on the stage of engineering a technical prototype of a composite wind power plant with a diffuser (WPPD). The area of a particular interest in the article is the mathematical aspect of the engineering stage. The article presents a theoretical study as well as experimental and practical data essential to obtain an effective shape of the diffuser. Here are also given engineering calculations and results of patent researches and field tests.

The authors calculate the most rational design parameters capable of ensuring the maximum speed in the area of the blades. This leads to an increase in the generated electricity, since it depends on the speed cubed. The increase in speed is stipulated by the passage of the air flow through the narrow part of the diffuser into the area of expansion and is consistent with the Bernoulli equation. The differential equation relates the flow velocity to the cross-sectional area of the diffuser. It should be noted that its inner part is the surface of rotation of the generatrixes around the axis of the diffuser. The surface shape can be adjusted based on the obtained mathematical calculations. In the research, these curves are described in the form of polynomials of various degrees. After integrating the differential equation for each curve individually the best option is selected. Here is also given an example with a quadratic function, which was experimentally substantiated in earlier researches and is used to compare the effects received from different generators.

The described technology, with account taken of the shape of the generator fairings, contributes to the further improvement of the WPPD. The article serves as the basis for engineering a technical prototype of a mobile composite WPPD.

Key words: wind power plant; composite material; windwheel; diffuser; speed.

Introduction. Economic crises of the past decades have shown that many traditional measures can provide no more a balance between the three pillars of sustainable development: economy, environment, and social sphere. This imbalance urges Kazakhstan to focus more on conceptual studies and related events: researches in the sphere of sustainable energy [1]. Sustainable energy is a sphere of mass application of high technologies; it is a catalyst for extensive social and economic development which provides a higher quality of life and transition of the society to environmentally sound technologies.

During the Astana EXPO – 2017 exhibition, the National Center for State Scientific and Technical Expertise (NCSSTE) held an international forum entitled “Integration of Science and Business”. In his report “Energy of Kazakhstan: Yesterday, Today, Tomorrow”, President of the NCSSTE listed the project described in the present paper among the four best Kazakhstani innovations in the field of green technologies. The project in question is aimed at creating a model prototype of a composite wind power plant with diffuser (WPPD) [2].

Research methods. Engineering and designing of the WPPD technical prototype demanded the usage of theoretical and applied research methods, including resource-saving techniques of processing (composites) CMs [4], tests, and analysis of the influence of the shape of the WPPD units on the amount of the produced energy [5]. The energy output of the wind turbines grows in proportion to the wind speed cubed. Availability of a diffuser leads to a decrease in pressure in the expanding section, which causes an increase in the air-flow velocity in the convergent section of the diffuser. The process of the flow motion is simulated with the help of the conservation of mass differential equation relating the flow velocity to the cross-sectional area of the diffuser. In order to describe the generatrixes of the inner surface of the diffuser there were used polynomials of various degrees that lead the mass conservation equation to the differential equations with separable variables. The analysis of the results showed that the shape of the generatrix of the construction in question makes no significant effect on the flow velocity increase near the wind wheel. This can also be backed up by the results of some tests of WPPD models carried out by the researchers from Buketov Karaganda State University in 2018.

Subsequent mathematical investigations reveal the influence of the geometric parameters of the fairings on the increase in the air-flow rate by 12-13% [5]. These calculation data are the basis for further experimental design and technological work essential for the creation of a technical prototype in order to obtain acceptable output parameters of the WPPD.

Parameters and advantages of the WPPD. Due to the grants from the Committee of Science of the Republic of Kazakhstan, there were constructed experimental prototypes [3] of a composite WPPD with the following parameters: mass – 95 kg, tower height – 4 m, designed capacity – 1 kW, temperature range – between 50° C below zero to 80° C above zero, material – fiberglass, service age – 20 years. Generation of current begins when the intense wind speeds range from 4 to 25 m/s.

It is worth noting that today there are only 4 or 5 types of wind power plants with diffuser. The states currently engaged in their construction are USA [4], Japan [5,6], UK [7] and Kazakhstan (figure 1).

WPPD in the USA WPPD in Japan WPPD in UK WPPD in Kazakhstan

Figure 1 – Various types of WPPD in the world

WPPDs made outside Kazakhstan are stationary, i.e. they are not mobile. Unlike them, the WPPD in question is mobile. Mobility is achieved due to the smaller size of WPPD compared to the common types of wind turbines. Assembly (and disassembly) of the WPPD in the field conditions takes no more than 2-3 hours and can be carried out by 3 people without any special lifting devices.

Advantages of the described wind power plant include its ease of use, high maintainability, climate resistance, safety of a wide range of applications, quiet operation, low metal consumption, attractive design, lack of radio interference and some others. It is very convenient for those people whose jobs and occupations demand frequent moving: cattle breeders, geologists, tourists, fishermen, rescuers and other consumers, especially those living or working in numerous remote and hard-to-reach locations of Kazakhstan.

The diffuser of the wind turbine in question turns to the wind with its narrow part and increases the speed of the air flow. It also protects the windwheel from the sun, birds, moisture, dust, etc. The WPPD is a reliable, noiseless and environmentally friendly source of energy.

Efficiency of the wind power plant with diffuser. The power of impeller type wind turbines (with horizontal axis of rotation) is calculated according to the formula [8,9]:

$$P = kD^2V^3. \tag{1}$$

D – diameter of the windwheel; V – wind speed; coefficient k depends on air density, wind energy utilization coefficients, transmission mechanism and generator.

Design characteristics of the compact wind turbine. According to formula (1), generation of power by the wind power plant depends on wind speed, diameter, shape and material of the windwheel. Relation

(1) shows that the increase of power is proportional to the squared diameter of the area swept by the windwheel. Thus, for example, if the blade is lengthened by 3 times, then the output power will increase by 9 times. This, certainly, causes a set of problems connected with material requirements, increased construction costs, ensuring strength, stability, etc. In this regard, small scale wind turbines are more reliable.

It seems more preferable to achieve the increase of power capacity by using other multiplicands in (1), since it depends, for instance, on wind speed cubed. This is a more determining factor. Wind speed depends not only on numerous climatic factors, but also on the type of the land surface and height above the ground. Various obstructions on the ground and friction of the lower layers against the earth's surface reduces the speed of the wind flow. Yet, it is at lower heights that turbulence of wind increases. If you take some random fixed place meeting all the necessary wind power plant dimension criteria, you will see that even within its boundaries the wind will frequently change its vector and “diffuse” kinetic energy in different directions [10]. Therefore, it is desirable to have such an air stream in which all particles will move in one specified direction. This can be achieved by ordering motion of particles, for instance, with the help of a horizontal tube or a diffuser. This will make the air flow less turbulent and directed [11] perpendicular to the plane of the windwheel rotation. Remarkably, the efficiency of the latter will increase significantly, especially if a diffuser is used, since the flow speed near the blades is higher compared to the speed outside the diffuser. This, according to formula (1), increases the power considerably. However, in the blades there may also arise significant centrifugal (tensile) stresses proportional to the density of the material and the square of the rotational speed. The increase of angular speed can be compensated by the corresponding decrease in the mass of the windwheel, if modern lightweight materials are used instead of metal.

The urgency of such problems as energy fuel price rises and new ecological requirements became apparent in the late 20^{th} century and coincided in time with the development and production of composites – materials with specified properties. Composite materials are materials formed by means of volumetric coupling of chemically heterogeneous constituents. They combine best properties of their constituents: strength, ductility, wear rate, low density, etc. It is remarkable that the composition itself is distinguished by such properties that none of the components, when taken separately, possesses. The most important of these properties include high specific strength, stiffness of the reinforced structure and the possibility of their variation by choosing particular constituents, modifying the structure, etc. [12].

Wind turbine power output grows proportionally to the cube of wind speed. Availability of the diffuser contributes to the decrease of pressure in its expanding section. This causes an increase in speed of the air flow and kinetic energy in the narrow part of the diffuser [13, 14] where the windwheel is placed (figure 2).

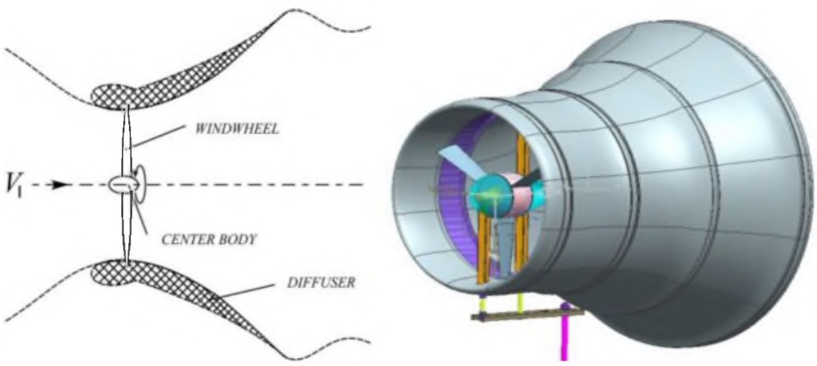


Figure 2 – The main scheme and a model prototype of a windwheel with the diffuser

In a common type of the wind-driven power plant there chiefly interact 2 key parts: its generator and the blade exposed to the unrestricted air environment. Unlike the common type of the wind power plant, the WPPD under consideration has an additional mechanism of interaction: its windwheel and a diffuser in the restricted airflow. This gives rise to a wide range of new theoretical and technical problems and tasks connected with aerodynamics and oscillations, stability and strength, electrodynamics, etc.

Mathematical justification for the use of a diffuser. Without dwelling on the complex mechanisms of the processes inside the diffuser, we shall consider a one-dimensional motion of incompressible fluid (air). To find the simplest analytical dependence of the flow speed distribution along the axis of the diffuser, we shall use the mass conservation equation [15]:

$$\frac{1}{V}\frac{dV}{dx} + \frac{1}{S}\frac{dS}{dx} = 0 \,. \qquad (2)$$

The internal generatrixes of the diffuser with an airfoil in its longitudinal section can be described by using a parabola $y=a+bx^2$ in accordance with Figure 3.

Then the cross-sectional area of the rotating body will be: $S = \pi * y^2(x) = \pi(a + bx^2)^2$, if we apply this relation to formula (2), we shall get an ordinary differential equation with separated variables

$$\frac{dV}{V} = -4\frac{bx}{a+bx^2}dx \,.$$

Using the method of separation of variables, the general solution can be presented in the form:

$$V = \frac{c}{(a+bx^2)^2} \,,$$

where c – the constant of integration.

Using the experimental ratio $V = 1{,}27\ V\infty$ [16], we shall obtain the formula

$$V = \frac{1.27a^2V_\infty}{(a+bx^2)^2} \,,$$

which, considering the real dimensions of our WPPD: $a=0.5$ *m.*, $b = 0.35$ m, V_∞ - wind speed outside the diffuser.

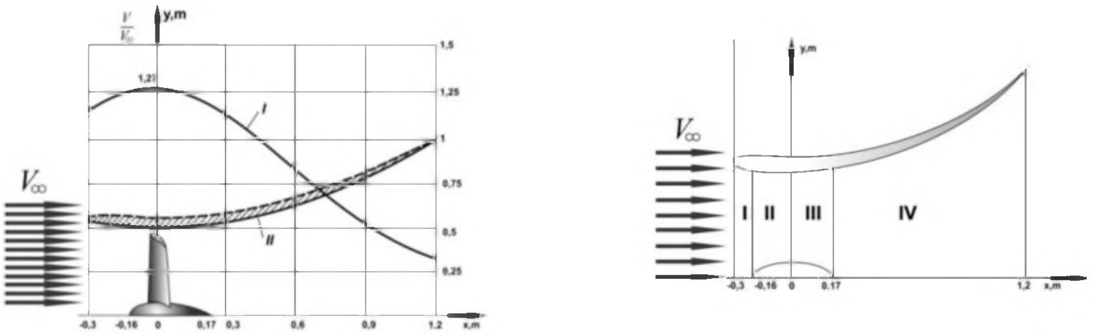
Here: $V_{input} = 1.13\ V_\infty$; $V_{outlet} = 0.32\ V_\infty$.

The obtained speed distribution and diffuser profile are presented in figure 3*a*.

As it was specified above, with the consideration of formula (1), the experimental theoretical relation $V = 1.27\ V\infty$ - requires doubling of the output energy of the wind turbine, such as $1.27^3 = 2.05$.

These calculations are made for the diffuser without taking into account the area of the windwheel.

Air-flow velocity coefficients with the consideration to the wind wheel. If we equip the diffuser with a center body – wind fairings in the form of combined paraboloids of rotation, this can alter the speed profile. To obtain numerical data, the internal content of the diffuser is divided into 4 zones, whose longitudinal section contains flat areas for separate integration. As shown in figure 3*b*, these areas are bounded by curved lines – the generatrixes of the diffuser (on the inside) and the wind turbine fairings. The obtained solutions of the differential equation are consistent at the boundaries of these areas.



a *b*

Figure 3 – *a*) curve I – speed distribution along the diffuser axis;
curve II – inner generatrix of the diffuser profile; *b*) division of the diffuser section into zones

After solving the tasks with the consideration of division into zones, we shall obtain the corresponding profiles of flow speeds, similar to the ones shown in Fig. 3*a*. For different types and sizes of the generator there were obtained the following values of input speed, speed at the output of the diffuser, and speed in the zone of the windwheel:

$$V_{input} = k_1 V_\infty,\ V_{max} = k_2 V_\infty,\ V_{outlet} = k_3\ V_\infty.$$

where $k_1 \epsilon [1.06; 1.1]$, $k_2 \epsilon [1.21; 1.28]$, $k_3 \epsilon [0.29; 0.31]$.

The average value of the wind amplification coefficient k_2 equals to 1.245. This leads to an increase in power by up to 1.93 times.

Results of field tests. The first field tests were carried out on the mobile stand-car "Gazelle" with the WPPD and instruments installed on it. This is an affordable and effective way of testing.

Figure 4 presents the results of testing the first WPPD prototype. The curved lines show that the voltage produced by the WPPD is 1.4-1.5 times higher than that produced by the wind turbines without a diffuser. This means that the diffuser almost doubles the power capacity of the wind power plant.

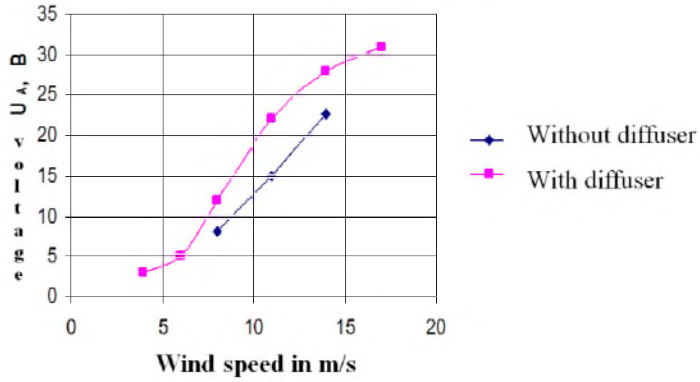


Figure 4 – Voltage U_A dependence on wind speed

These results can be of use when designing other types of WPPD. They can be also helpful for the construction and research of experimental models of wind power plants.

Figure 5 shows the output values of the accumulated at 24 h. capacities P_{24} of the most recent prototypes: WPPD-3 and WPPD-4, constructed in 2014 and 2017 respectively. They differ in weight and other characteristics. It should be noted, that in 2017 there were applied various rotary devices. The test results of 2017 are presented in the form of graphs reflecting operation of WPPD-4(1) and WPPD-4(2) when the electrical load (battery) is connected to it. For comparison, we also show the data for WPPD received earlier in 2014.

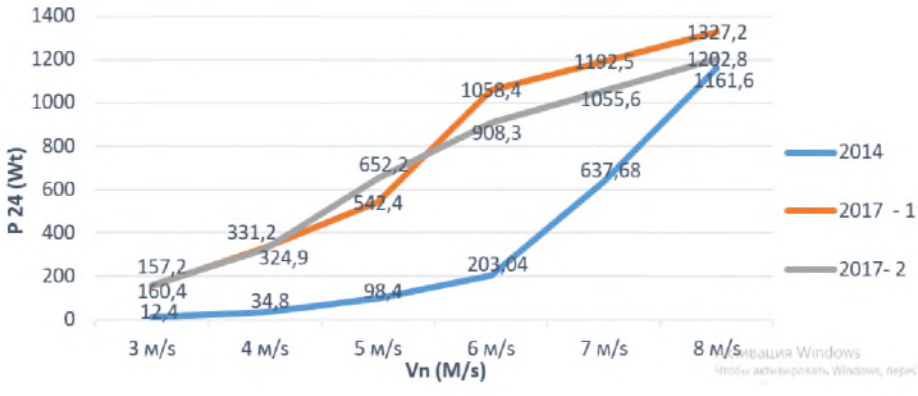


Figure 5 – Graphs of power generated by WPPD-3, WPPD – 4(1) and WPPD – 4(2)

Variability of the values of the wind turbine output parameters in the two graphs above does not exceed 10% at wind speeds of 6-8 m/s. Apparently, the variability is caused by the peculiarities of the rotating device. At speeds of 3 to 6 m/s, the variability is insignificant.

From the comparison of the three curved lines depicted in figure 5, it follows that there is a “band” of numerical values of energy for the 2017 electric generator, whose average points are 5.5 times higher than for the WPPD with an electric generator of 2014.

Conclusion:

1. The work in question helps to design a prototype with competitive parameters which will serve as the basis for small-scale production.

2. In the range of wind speed of 4-7 m/s, the new generator provides a significant increase in the accumulated energy.

3. Rural residents have problems with electricity availability, therefore this issue still remains relevant [8,16,17]. The WPPD in question can solve these problems to some extent.

4. The use of this WPPD will have both economic and environmental effect and provide energy independence at the local levels.

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ДИФФУЗОРЫ БАР КОМПОЗИЦИЯЛЫҚ МОБИЛЬДІ ЖЕЛЭНЕРГЕТИКАЛЫҚ ҚОНДЫРҒЫ

Аннотация. 2002 жылы облыс әкімдері қатысқан кездесуде мемлекет басшысы ауылдардың мемлекетте өндірілген энергияның 10%-ын ғана тұтынатынын атап өтті. Бұл тек энергетикалық желілердің нашарлығымен қатар көптеген ауылдың қашық орналасуы және халық тығыздығының төмендігіне байланысты деп түсіндірілді. Осы жағдайларды ескере отырып, оларды кез-келген қол жетпейтін жерге оңай жеткізуге болатын автономды энергия көзімен қамтамасыз етуге баса назар аударылды. Сол уақыттан бері 20 шақты жыл өткенімен, ауыл тұрғындарының энергияны тұтыну мөлшері бірнеше есе төмендеп кеткені белгілі болды.

Осы туындап отырған қиындықтан шығу үшін тұтынушыларды электр энергиясының түрлі шағын көзімен қамтамасыз ету қажет. Солардың арасынан күннің, желдің және т.б. орасан табиғи потенциалы қолданылатын, жаңартылатын энергия көзін ерекше атап өтуге болады. Олар адам өмірінің сапасына жақсы әсер ете бере отырып, табиғат пен қоғамның экологиялық тепе-теңдігін бұзбайды. Сонымен бірге, жел энергетикасы бағытын айрықша атап өту қажет, өйткені елдің жел кадастры ауа ағынына қолжетімді екендігін растап отыр. Көптеген сарапшылардың айтуы бойынша далалық жазықтар мен үстірттердің кеңдігі жел энергетикасының дамуына оңтайлы болып саналады.

Отандық ғалымдар энергия тиімділігі мен жергілікті жердегі сапалы қолданысын дәлелдеген жел турбиналарының бірнеше түрін жасап шығаруда. Осы стационар энергомашиналарымен салыстырғанда, зерттелінетін диффузоры бар композиттік желэнергетикалық қондырғы (ДЖЭҚ) жылжымалы болып келеді. Бұл қондырғының жеңіл және берік композициялық материалдан – шыны талшықтан жасалуы оның мобильді болуын қамтамасыз етеді. Сонымен қатар, қолжетімді инженерлік әдістер мен есептеу негізінде дайындалған диффузордың арнайы формасы конструкция дизайнының жаңашылдығын айқындайды.

Мақала диффузоры бар композициялық желэнергетикалық қондырғының (ДЖЭҚ) техникалық прототипін жобалаудың математикалық бөліміне арналған. Жұмыста диффузордың тиімді формасын алу үшін теориялық зерттеу және эксперименталды-тәжірибелік деректер келтірілді. Инженерлік есептеу, жеке ғылыми зерттеулердің, патенттердің және далалық сынақтардың нәтижелері қолданылды.

Қалақ аймағында максималды жылдамдықты қамтамасыз ететін конструкцияның ең ұтымды параметрлері есептеледі. Бұл өндірілетін электр энергиясын арттырады, себебі ол жылдамдықтың үшінші дәрежесіне тәуелді. Жылдамдықтың артуы диффузордың тар бөлігі арқылы оның кеңею аймағына өтуіне негізделген және Бернулли теңдеуіне сәйкес келеді. Дифференциалдық теңдеулер ағынның жылдамдығын диффузор қимасының ауданымен байланыстырады. Сонымен қатар, оның ішкі бөлігі – диффузор осінің айналасындағы түзуші сызықтардың айналу беті. Беттің пішінін алынған математикалық есептеу негізінде реттеуге болады. Бұл қисықтар әртүрлі дәрежедегі полиномдар түрінде сипатталған.

Әрбір сызық үшін айнымалылары ажыратылатын дифференциалдық теңдеу жеке-жеке интегралданады және желаяқ аймағында жел жылдамдығының күшеюі коэффициентінің шамасы бойынша оңтайлы нұсқа таңдалады. Алдыңғы эксперименталды жұмыстарға негізделген және басқа генераторлар әсерімен салыстыру үшін квадраттық функция мысалға келтірілген. Санға дейін жеткізілген аналитикалық шешім жел қондырғысын пайдалану шарттарына барынша жақындатылған сынақтарда дәлелденген. Алынған графиктер өндірілген энергия үшін диффузоры бар композициялық желэнергетикалық қондырғының (ДЖЭҚ) түрлі үлгілерінде қуат өсімін екі және одан да көп есе көрсетеді.

Мақалада соңғы бірнеше жыл бойы әзірленген және жасалған композиттік тәжірибелік үлгілердің әртүрлі нұсқаларын зерттеу нәтижелері көрсетілген. Олар бір-бірінен электрогенераторлардың физика-геометриялық параметрлерімен де, шыны пластиктен жасалған жел илегіштің жиынтықтаушы элементерімен де ерекшеленеді. Заттық сынақ нәтижелерінің ішінде ең тиімді нұсқа ДЖЭҚ - 4 конструкциясы болып саналады. Оған сәйкес материалдар «Астана. ЭКСПО-2017. Болашақ энергиясы» халықаралық мамандандырылған көрмесінде ұсынылған және сарапшылар мен қоғам өкілдерінің қызығушылығын тудырды.

Сонымен қатар, генератордың айналаға ағуын есепке ала отырып, сипатталған әдістеме ДЖЭҚ-ны одан әрі жетілдіру бойынша нәтижелерге әкеледі. Мақала мобильді композициялық ДЖЭҚ-ның техникалық прототипін құру үшін негіз болып саналады.

Түйін сөздер: желэнергетикалық қондырғы, композициялық материал, жел дөңгелегі, диффузор, шыны пластик.

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МОБИЛЬНАЯ КОМПОЗИЦИОННАЯ ВЕТРОЭНЕРГЕТИЧЕСКАЯ УСТАНОВКА С ДИФФУЗОРОМ

Аннотация. Ещё в 2002 году на совещании с руководителями областей Глава государства отметил, что село потребляет лишь 10% электроэнергии, производимой в стране. Это объясняется не только изношенностью энергетических сетей, но и отдаленностью многих аулов, а также малой плотностью населения. Исходя из этого был сделан акцент на обеспечение их автономными источниками энергии, которые легко можно доставить в любой труднодоступный пункт. С тех пор прошло почти 20 лет, а доля потребления электричества сельскими жителями упала в несколько раз.

Для выхода из такого бедственного положения имеет смысл обеспечить потребителей различными малыми источниками электрической энергии. Среди них можно особо выделить возобновляемые источники энергии, которые эффективно используют огромный природный потенциал Солнца, ветра и т.п. Они благотворно влияют на качество жизнедеятельности человека и не разрушают экологическое равновесие природы и общества. При этом можно выделить направление ветроэнергетики, поскольку ветровой кадастр страны подтверждает неисчерпаемость запасов достаточно доступных воздушных потоков. Наличие обширных площадей степных равнин и плоскогорных массивов, как отмечают многие специалисты, благоприятствует развитию ветроэнергетики.

Отечественными учеными разрабатывается несколько видов ветроустановок, которые уже доказали свою энергоэффективность и применимость в соответствующих местностях. В отличие от этих стационарных энергомашин разрабатываемая композиционная ветроэнергетическая установка с диффузором (ВЭУД) – переносная. Её мобильность обусловлена тем, что вся установка изготовлена из легкого и прочного композиционного материала - стеклопластика. При этом новизну конструкции придает особая форма диффузора, которая создана на основе доступных инженерных методов и расчетов.

Статья посвящена математической части этапа проектирования и опытного обоснования технического прототипа композиционной ВЭУД. В работе приводятся теоретическое исследование и экспериментально-практические данные для получения эффективной формы диффузора. Используются инженерные расчёты, результаты собственных научных исследований, патентов и полевых испытаний.

Вычисляются наиболее рациональные параметры конструкции, обеспечивающие максимальную скорость в зоне лопастей. Это приводит к росту вырабатываемой электроэнергии, так как она зависит от третьей степени скорости. Увеличение скорости обусловлено его прохождением через узкую часть диффузора в зону расширения и соответствует уравнению Бернулли. Дифференциальное уравнение связывает скорость потока и площадь поперечного сечения диффузора. При этом его внутренняя часть есть поверхность вращения образующих линий вокруг оси диффузора. Форма поверхности поддаётся регулированию на основе полученных математических расчетов. Эти кривые описаны в виде полиномов различных степеней.

Дифференциальное уравнение с разделяющимися переменными для каждой линии интегрируется по-отдельности и выбирается оптимальный вариант по величине коэффициента усиления скорости ветра в зоне ветроколеса. Приведён пример с квадратичной функцией, который был экспериментально обоснован в ранних работах и используется здесь для сравнения с эффектами от других генераторов. Аналитическое решение, доведенное до числа, подтверждено на испытаниях, максимально приближенных к условиям эксплуатации ветроустановки. Полученные графики для вырабатываемой энергии на различных образцах ВЭУД демонстрируют прирост мощности в два и более раза.

В статье отражены результаты исследований различных вариантов композитных опытных образцов, разработанных и созданных на протяжении нескольких последних лет. Они отличаются друг от друга как физико-геометрическими параметрами электрогенераторов, так и соответствующими им комплектующими элементами ветроколеса, изготовленных из стеклопластика. Из результатов натурных испытаний следует, что наилучшим вариантом является конструкция ВЭУД-4. Соответствующие ему материалы были представлены на Международной специализированной выставке «Астана.Экспо-2017.Энергия будущего» и вызвали значительный интерес как у экспертов, так и у представителей общественности.

Описанная методика, с учетом также обтекателей генератора, приводит к результатам по дальнейшему совершенствованию ВЭУД. Статья служит основанием для создания технического прототипа мобильной композиционной ВЭУД.

Ключевые слова: ветроэнергетическая установка, композиционный материал, ветроколесо, диффузор, скорость.

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REFERENCES

[1] Abykayev N.A., Kuznetsov O.L., Bekturganov N.S., Spitsyn A.T., Zeynullin A.A., Sheulin A.S. More on the perspectives of sustainable energy in future Kazakhstan until the year of 2050 // Bulletin of “Kazakhstan National Academy of Natural Sciences, 2 (2013). P. 5-34 (in Russ.). https://kaznaen.kz/?page_id=413.

[2] Ibrayev A. Power industry in Kazakhstan: yesterday, today, tomorrow. A slide from the presented report. Astana, 2017. 12 p. (in Russ.). http://nauka.kz/upload/files/adil_ibraev_-_energetika_kazahstana_vchera _segodnya_zavtra.pdf

[3] Bayshagirov Kh.Zh., Wind power plant // Innovation patent for the invention of a utility model granted in the Republic of Kazakhstan, N 802, (04.16.2012) (in Russ.). http://kzpatents.com/4-u802-vetrovaya-energeticheskaya-ustanovka.html

[4] Wajeeha A. This design for a cheap wind turbine inspired by the jet engine could revolutionize wind power technology // Wonderful Engineering. Technology, 2016 (in Eng.). https://wonderfulengineering.com/this-design-for-a-cheap-wind-turbine-inspired-by-the-jet-engine-could-revolutionize-wind-power-technology/

[5] Yuji Ohya, Takashi Karasudani. A Shrouded Wind Turbine Generating High Output Power with Wind-lens Technology // Energies journal, (03.31.2010). P. 634-649 (in Eng.). https://www.mdpi.com/1996-1073/3/4/634

[6] Nolten T. Japanese breakthrough triples wind power // BetterWorldSolutions. Netherlands, (06.06.2019) (in Eng.). https://www.betterworldsolutions.eu/japanese-breakthrough-triples-wind-power/

[7] Meetoo K. Wind turbines with 3D printed device // Designboom. Milan, 2011 (in Eng.). https://www.designboom.com/technology/krishan-meetoo-redesigns-wind-turbines-with-3d-printed-device/

[8] Tleuov A.Kh. Non-conventional energy sources // Foliant. Astana, 2009. 248 p. (in Russ.). https://www.twirpx.com/file/2258639/

[9] Masoud A.Z. Design and CFD analysis of airborne wind turbine for boats and ships // International Journal of Aerospace Sciences, 4 (1) (2016). P. 14-24 (in Eng.). http://article.sapub.org/10.5923.j.aerospace.20160401.03.html.

[10] Yablonsky V.S. A brief course of technical hydromechanics // State publisher of physical and mathematical literature, (1961). 356 p. (in Russ.). https://www.twirpx.com/file/2334808/

[11] Yemtsev B.T. Technical hydromechanics // Mechanical Engineering. M. (1987). 440 p. (in Russ.). https://www.twirpx.com/file/1933886/

[12] Karimbayev T.D., Luppov A.A. Model of fatigue life of composite materials. The main approaches // Composites and nanostructuresб 10, 1 (37), (2018). P. 1-13 (in Russ.). http://www.issp.ac.ru/journal/composites/2018/content-1-2018_en.pdf

[13] Siavasha N.K., Najafia G., Hashjina T.T., Ghobadiana B., Mahmoodib E. An innovative variable shroud for micro wind turbines // Renewable Energy, 145 (2020). P. 1061-1072. (in Eng.). https://www.sciencedirect.com/science/article/pii/S096014811930922X

[14] Kazuhiko Toshimitsu, Hironori Kikugawa, Kohei Sato, Takuya Sato, Experimental Investigation of Performance of the Wind Turbine with the Flanged-Diffuser Shroud in Sinusoidally Oscillating and Fluctuating Velocity Flows // Open Journal of Fluid Dynamics, 2 (2012). P. 215-221 (in Eng.). https://www.semanticscholar.org/paper/Experimental-Investigation-of-Performance-of-the-in-Toshimitsu-Kikugawa/cdea7d7b6862e6d7e86a21e354605ea4d6610d2f

[15] Povkh I.L. Technical hydromechanics // Mechanical Engineering. Leningrad, (1969), 524 p. (in Russ.). https://opac.mpei.ru/OpacUnicode/app/webroot/index.php?url=/notices/index/IdNotice:228514/Source:default

[16] De Renzo D. J., Zubareva V.V., Frankfurt M.O., Shefter Ya.I. Wind power recent developments // Energoatomizdat. M. (1982). 223 p. (in Russ.). http://gildiam.ru/Portals/0/doc/literature/Vetroenergetika.pdf

[17] Kalimoldayev M., Akhmetzhanov M., Kunelbayev M. Determination of the power interaction of the hydro turbine GRID with a fluid flow for a double-rotor micro hydro power plant // News of the National Academy of sciences of the Republic of Kazakhstan. Physico-mathematical series. Vol. 4, N 326 (2019), 59-67 (in Russ.). https://nauka-nanrk.kz/assets/assets/журнал%202019%204/physical%20and%20mathematical_04_2019.pdf

[18] Zdorovets M.V., Extract No. 2 from the minutes of the meeting of the National Scientific Council on the issues of "Energy and Engineering" // National Center for Scientific and Technical Expertise. Astana, 1 (1,2,3,4) (01.19.2018). P. 4-32 (in Russ.). https://www.ncste.kz/ru/energetika-i-mashinostroenie-2018