IRSTI 55.37.33

A. Dahham*, A.Zh.Kassenov, K. Abishev

Toraighyrov University, Pavlodar, Kazakhstan
E-mail: *abbas.dahham2015@gmail.com, Asylbek_kasenov@mail.ru, [1]abishev.k@tou.edu.kz*

Design and Performance of 1.5-Meters Radius Wind Turbine under High Wind Speeds Condition

Abstract. *Global warming is a serious challenge to civilizational development due to the increase in temperature because of exhaust gases. These gases, produced by burning fossil fuels, should reduce or replace the way energy is generated using renewable energy sources. Our study shows the ability of 1.5-meter reduce wind turbine to create a mechanical power to drive some mechanical devices under high wind speed conditions. This type of devices needs approximately 1460 watt (2 horses); the turbine designed with angle blade Beta 2 degrees and Lambda 10 to reach maximum benefit from the wind.*

The turbine is exposed to variable wind, as a result, the turbine generates the required power when the wind speed is from 9.3 to 9.7 m/s, when the generated power is less than the required one, the device can work with less efficiency, and more power is better within the limits that do not damage device.

Keywords: *renewable energy, small wind turbine, mechanical power, small devices power.*

DOI: doi.org/10.32523/2616-7263-2023-144-3-20-28

Introduction

Excluded is the history of studying gas exhaust vehicle components on human health and environmental coverage from 1930 to 2014. According to literature data, the most dangerous components of exhaust gases are gases (SO_3, NO_x), polyromantic hydrocarbons (pyrene, phenan, acenaptylene and fluoranthene), particulate matter PM1 and PM25 (soot, ash, metal oxides and salt).

It has been shown that the conversion of car stone (Catalytic converter) to new types of fuel (biodiesel, hybrid electrical installations, bioethanol) does not reduce the harmful effects of exhaust gases on the city's ecology and human health. The mechanism of the negative effect of engine exhaust, according to the literature, is the induction of a local inflammatory reaction in the airways, and then a systemic inflammatory reaction [1].

To date, the global fleet of vehicles exceeds 600 million units, of which 83-85% are cars, 15-17% are trucks and buses. If you put them bumper to bumper, you get a 4 million km long ribbon that could encircle the earth around the equator 100 times. The share of vehicles in air pollution in cities reaches 70-90%, which creates fairly stable and extended zones, within which sanitary and hygienic standards for air pollution are exceeded several times [2].

Climate change is changing our economies, health and communities in many ways. Scientists warn that if we fail to substantially stop climate change at this stage, the consequences could be catastrophic. One of the most negative effects is hurricanes, tornadoes and other storms caused by climate change and water evaporation may become more frequent [3].

The constant emission of nitrogen oxides in recent years is mainly associated with the development of vehicles. In addition, the trend towards fuller use of fuel also results in higher NO emissions, as higher engine efficiency is associated with higher temperatures. The number

of emissions also grows with an increase in the speed of traffic, and it is nonlinear: the amount of NO grows faster. Thus, the concentration of NO on highways also increases with increasing vehicle speed. Anthropogenic pollution of the atmosphere with nitrogen oxides becomes critical in densely populated cities, where precipitation is more frequent. The highest concentration of emissions in cities reaches 800-1200 μg/m3.

Emissions of the seven most common harmful emissions estimated: oxide, hydrocarbons, nitrogen dioxide, soot, sulfur dioxide, lead compounds and heavy emissions. On average, the total mass of polluting emissions from mobile sources is about 12 million tons per year, including from road transport - 95%, air transport - 2.5%, sea and river transport - 2.8% [3].

Actually, there is not enough research about the alternative ways to use renewable energy under high wind speed conditions. There are some attempts to create mechanical powers enough for small devices in different ways as following:

Related to vehicles, the compressor is one of the important devices that need to find clean resource to drive it. One way mentioned by studies is that reduce the heat load inside the vehicle to reduce time needs to operate the compressor. Thus, reduce the fuel consumption [4].

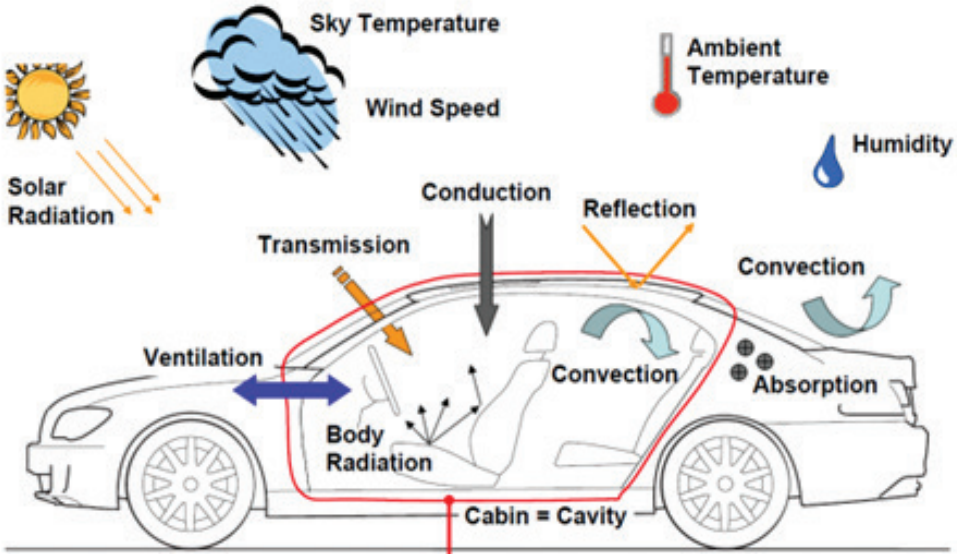

Figure1. Thermal imbalance [4].

A number of tests carried out to study the fuel consumption of various types of vehicles and weather conditions. Two series of tests have done, the results showed that the air conditioner could consume fuel from 1.0 to 2.45 l / 100 km (from 21 to 53%) [5,6]. Researchers have found many ways to reduce excessive fuel consumption through air conditioning. One made using a variable displacement compressor (VCC) that used some scientists [6]. Not all of these studies have used renewable energy to drive small devices.

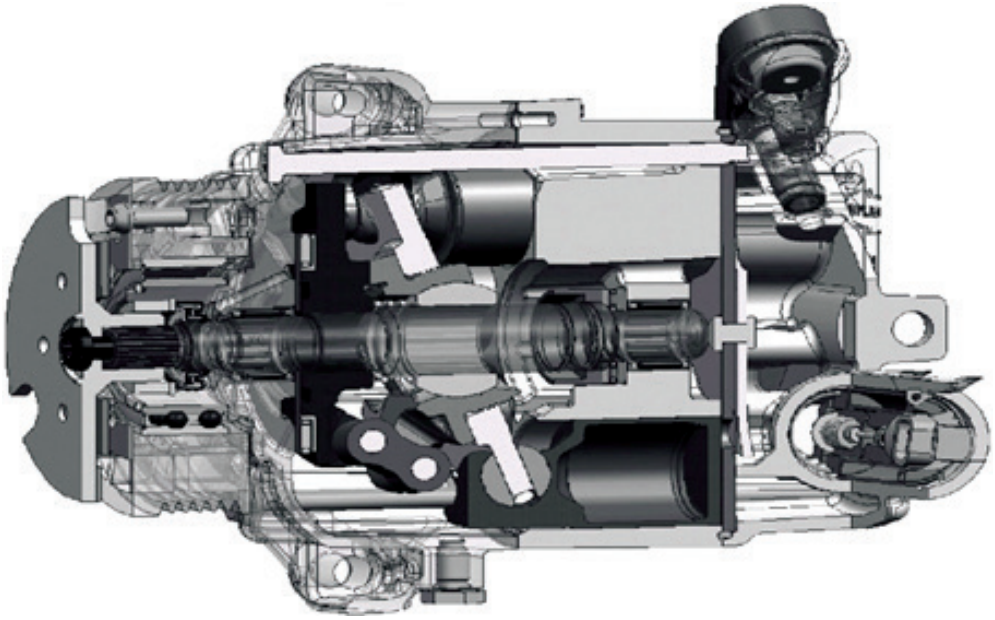

Figure 2. Variable displacement compressor (VCC) [6]

There are lots of attempt that used turbine as alternative energy. One of them is using turbine on the car as shown in figure below

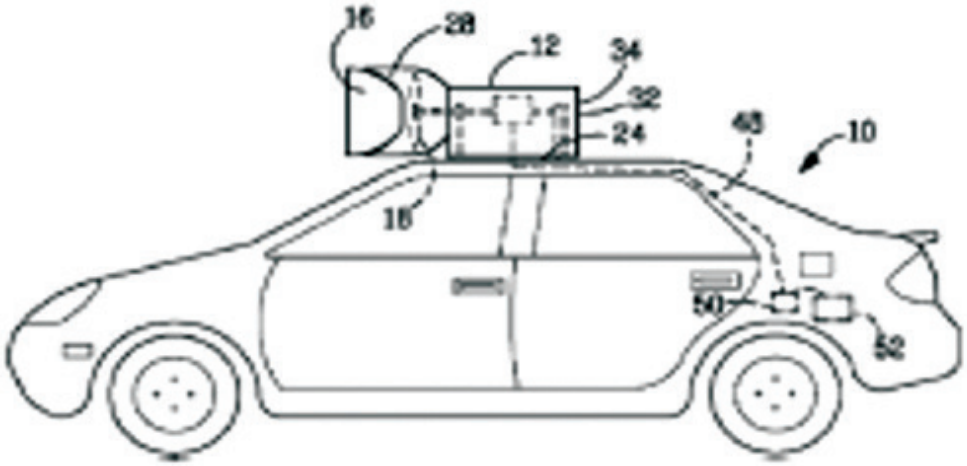

Figure 3. Model of wind turbine to generate energy [7]

The turbine can be a promising tool to utilize wind energy to generate electricity from self-renewing resources to power the car [7].

Also, A Chinese farmer has invented a wind-powered electric car that he says could save his country from the pollution caused by its rapidly growing car market [8].

Figure 4. Chinese farmer wind turbine [8]

This study illustrates ability of use 1.5-meter radius ordinary wind turbine to generate optimal mechanical power for some small devices about 1460 watt (2-horsepower) to reduce fuel consumption and its exhausted gases and to determine alternative method to drive the devices by using renewable energy under high wind speed.

Mathematical method equations

The mechanical power obtain from the turbine can be count by following many different equations, some that depend on the number of blades and others without takes it in account but depending on the prevent experiments. For this type of turbines that deals with slow wind speed does not exceed 20 m/s we can take the number of blade only 3 blades to avoid the damage or burn the turbine. The general equation can expresse as follows:

$$P = \frac{1}{2} * \rho * S * V^3 \tag{1}$$

where ρ is the air density 1.204 kg/m3;

S – washed area2;

V — wind speed m/s.

In any case, this is an equation for optimal conditions, where in 1916 the German scientist Albert Betz found that the power available from wind power is (59.3%) the kinetic energy of the wind, so

$$Pavail=Pv*Cp \tag{2}$$

From the equation above important factor in turbines, that called the turbine power coefficient C

$$C_p = \frac{P_{avail}}{P_v} \tag{3}$$

Therefore, the final power equation is as follows:

$$P = C_p * \frac{1}{2} * \rho * S * V^3 \tag{4}$$

Turbine Modeling Assumptions

There is an assumption to start modeling the turbine in ideal conditions:

1. Consider the blades to be the same and homogeneous, having the same moment of inertia and the same parameters;
2. The coefficient of friction for air is zero;
3. The wind speed is uneven when it enters the zone of the turbine blades.

Results and discussion

Fossil fuel emissions have a detrimental effect on the climate, and people have prompted many scientists to think about finding alternative energy. The energy that promises a good and sustainable future without harmful emissions is wind energy. Therefore, in this experiment, an attempt was made to find the power to drive large devices that consume little power without consuming 2-horsepower. By applying the equation related to wind flow in Matlab as shown below.

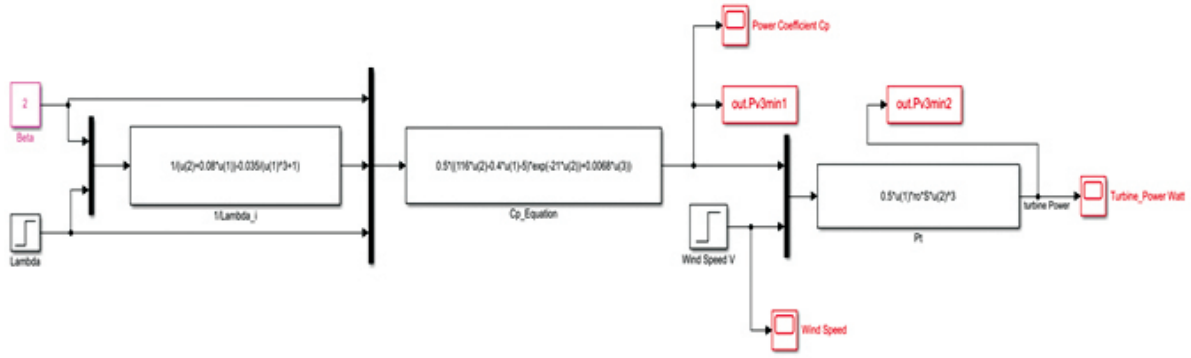

Figure 5. Representing and finding the power coefficient and turbine power by Matlab

As shown in the Figure 5 the wind range applied on the turbine which is between 9.3 to 9.7 m/s gives the required amount of mechanical power to drive the specific device as shown in the figures below:

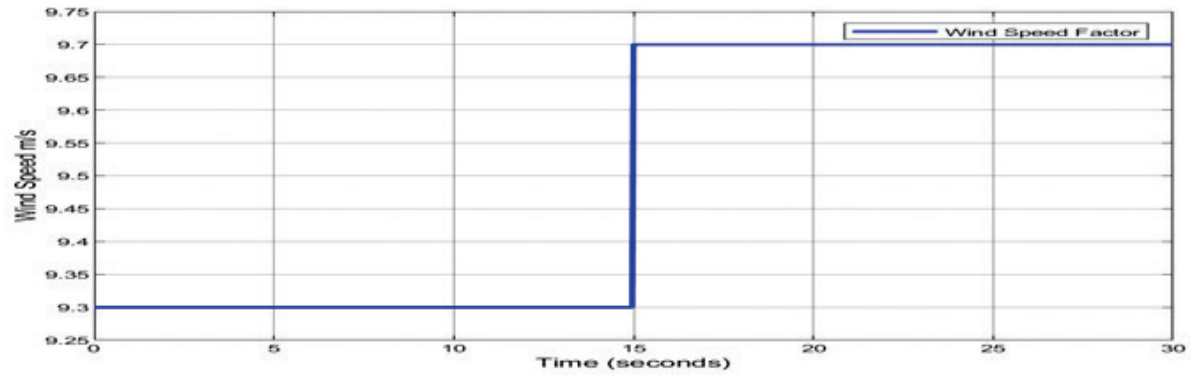

Figure 6. Wind Speed variety through the time

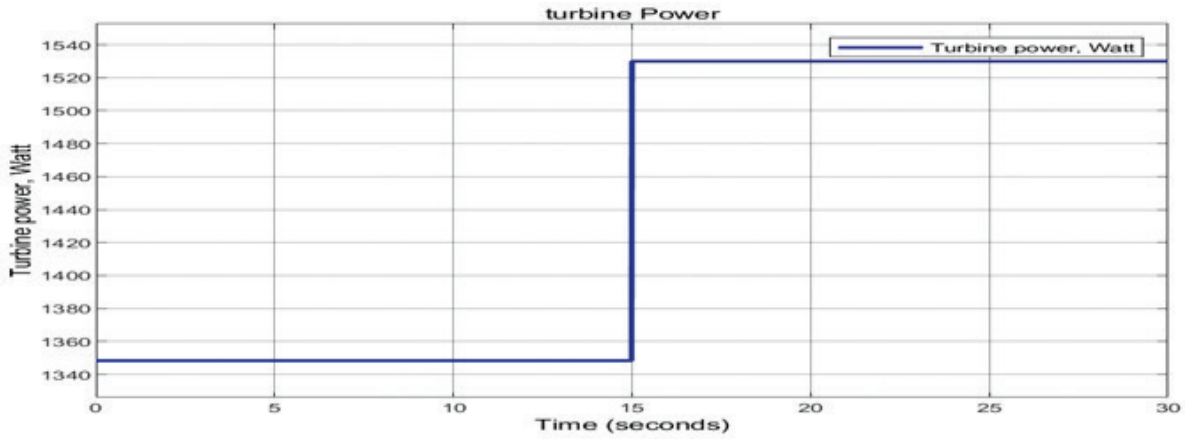

Figure 7. Mechanical power at wind speed around 9.3 to 9.7

In addition, it can be seen from the figures that in order to achieve high power, the wind speed should be about 9.55 m/s that achieves the require energy for small devices like air conditioner compressor that is about 1460 watt (2-horsepower).

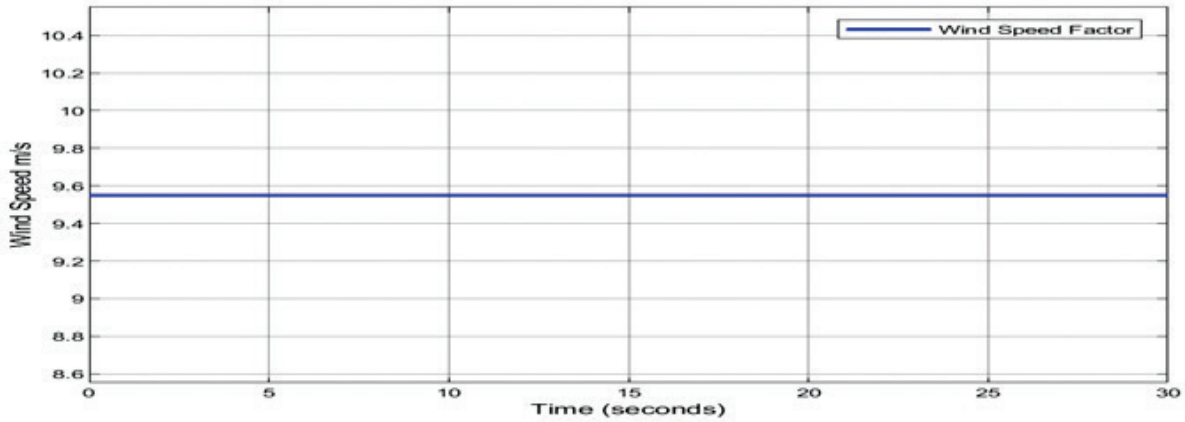

Figure 8. Wind speed fixed at 6m/s

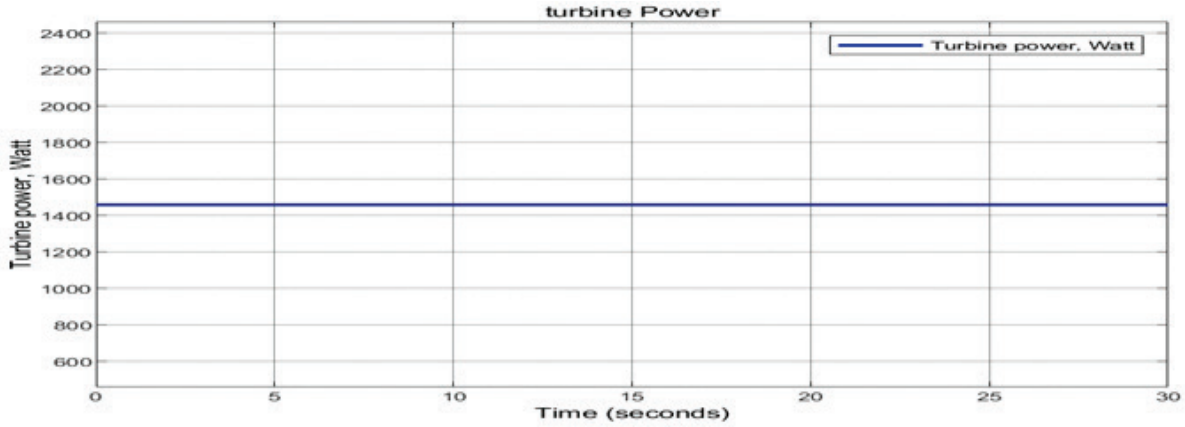

Figure 9. Turbine power at fixed wind speed 9.55 m/s

The device could work with low efficiency at low wind speed. Although high wind speeds give good operating conditions, they do not exceed the damage limit.

Conclusion

The renewable energy is the best way to reduce the negative effect of the exhausted gases produced from the fossil fuel. One of the renewable energy sorts is the wind energy. Based on experience, wind turbines give zero emissions, but we can only get 59% of wind energy depending on the Betz limit. For a turbine with a radius of 1.5 meters, the mechanical power required for specific devices can be obtained with a wind speed of about 9.55 m/s , where gives about 1460 watt (2 horsepower) for optimal condition. However, at low wind speed, the device could work with less efficiency and for high wind speed could work better if it does not exceed the speed that damages the device.

References

1. Ichingyur Yu., Altiparmak D. Vliyanieczetanovogochislatoplivaidavleniyavpry`skanakharakteris tikiivy`brosy` dizel`nogodvigatelya s pryamy`mvpry`skom. Preobrazovaniee`nergiiiupravlenie [Effect of fuel cetane number and injection pressure on a DI Diesel engine performance and emissions], ЕЛСЕВИЕР [ELSEVIER], 44, 389-397 (2003).https://doi.org/10.1016/S0196-8904(02)00063-8.Available at: https://www.sciencedirect.com/science/article/abs/pii/S0196890402000638. [in Russian].(accessed 08.04.2023).

2. Gogoladze O. Global`noe poteplenie izmenit Zemlyu ot avtomobilistov [Global warming will change the Earth from motorists]. Available at: https://hightech.plus/2018/08/22/globalnoe-poteplenie-izbavit-zemlyu-ot-avtomobilistov2018- 08 -22. htm (accessed 01.05.2023).

3. Khinvud A. Novy`jotchet: issledovanie problem, svyazanny`kh s modifikacziejsolnechnojradiaczi i. Novosti OON [New report: A study of the problems associated with the modification of solar radiation. UN news]. Available at:https://www.unep.org/ru/novosti-i-istorii/istoriya/novyy-otchet-issledovanie-problem-svyazannykh-s-modifikaciey-solnechnoy 2023-02-28.htm (accessed 25.03.2023).

4. Khuang K.D. Intellektual`naya sistema avtomobil`noj ventilyaczii na solnechny`kh batareyakh [Intelligent Solar Vehicle Ventilation System], Prikladnaya e`nergetika [Applied Energy], 80, (2), 141-154 (2005).

5. Fayazbakhsh M. A., Bahrami M. Comprehensive modeling of vehicle air conditioningloadsusingheat balance method //SAEtechnicalpaper. – 2013.– Т. 2013.–С. 1507.DOI: 10.4271/2013-01-1507. – URL: https://www.researchgate.net/publication/269250427. (accessed: 01.01.2023).

6. Zima M. Wang M. Kadle P. Bona J. Improving the Fuel Efficiency of mobile A\C Systems with Variable Displacement Compressor //SAEtechnicalpaper. 2014-01-0700. DOI: 10.427/semi.2014.01.0700. – URL: https://www.sae.org/publications/technical-papers/content/2014-01-0700/. (accessed: 01.05.2023).

7. https://alcse.org/the-american-wind-powered-car/ (accessed: 25.03.2023).

8. https://www.zdnet.com/article/chinese-farmer-builds-his-own-wind-powered-car (accessed: 25.03.2023).

А.В. Дахам, А.Ж. Қасенов, К.К. Әбішев
Торайғыров Университеті, Павлодар, Қазақстан

Жоғары жел жылдамдығы жағдайында радиусы 1,5 метрлік жел турбинасы дизайны мен тиімділігі

Аңдатпа. Жаһандық жылыну – пайдаланылған газдардың әсерінен температураның жоғарылауына байланысты өркениеттің дамуы үшін күрделі сынақ. Қазба отындарын жағу арқылы өндірілетін бұл газдар жаңартылатын энергия көздерін пайдалану арқылы энергия өндіру әдісін азайтуы немесе ауыстыруы керек. Біздің зерттеуіміз желдің жоғары жылдамдығы жағдайында кейбір механикалық құрылғыларды жүргізу үшін 1,5 метрлік жел турбинасының механикалық қуат өндіру қабілетін көрсетеді. Құрылғының бұл түрі шамамен 1460 ватт (2 ат күші) қажет; Турбина желдің пайдасын барынша арттыру үшін Beta 2 градус және Lambda 10 қалақ бұрышымен жасалған. Турбина ауыспалы желдің әсеріне ұшырайды, соның нәтижесінде турбина желдің жылдамдығы 9,3-тен 9,7 м/с-қа дейін қажетті қуатты өндіреді, қажетті қуаттан аз болса, құрылғы аз тиімділікпен жұмыс істей алады, ал электр қуаты көп болады құрылғыны зақымдамайтын шекте жақсырақ.

Түйін сөздер: жаңартылатын энергия, желтурбинасы, механикалық энергия, шағын құрылғылардың қуаты.

А.В. Дахам, А.Ж. Касенов, К.К. Абишев
Торайгыров Университет, Павлодар, Казахстан

Проектирование и эффективность ветряной турбины радиусом 1,5 метра в условиях высокой скорости ветра

Аннотация. Глобальное потепление представляет собой серьезный вызов цивилизационному развитию из-за повышения температуры из-за выхлопных газов. Эти газы, образующиеся при сжигании ископаемого топлива, должны сократить или заменить способ производства энергии с использованием возобновляемых источников энергии. Наше исследование показывает способность 1,5-метровой ветряной турбины создавать механическую мощность для привода некоторых механических устройств в условиях высокой скорости ветра. Для этого типа устройств требуется примерно 1460 Вт (2 лошадиные силы); турбина спроектирована с углом наклона лопастей Beta 2 градуса и Lambda 10 для получения максимальной выгоды от ветра. Турбина подвергается воздействию переменного ветра, в результате чего турбина вырабатывает требуемую мощность при скорости ветра от 9,3 до 9,7 м/с, при вырабатываемой мощности меньше необходимой устройство может работать с меньшим КПД, и больше мощность лучше в пределах, которые не повреждают устройство.

Ключевые слова: возобновляемая энергетика, ветродвигатель, механическая энергия, мощность малых устройств.

References

1. Ichingyur Yu., Altiparmak D. Vliyanieczetanovogochislatoplivaidavleniyavpry`skanakharakteris tikiivy`brosy` dizel`nogodvigatelya s pryamy`mvpry`skom. Preobrazovaniee`nergiiiupravlenie [Effect of fuel cetane number and injection pressure on a DI Diesel engine performance and emissions], [ELSEVIER], 44, 389-397 (2003).https://doi.org/10.1016/S0196-8904(02)00063-8.Available at: https://www.sciencedirect.com/science/article/abs/pii/S0196890402000638. [in Russian].(accessed 08.04.2023).

2. Gogoladze O. Global`noe poteplenie izmenit Zemlyu ot avtomobilistov [Global warming will change the Earth from motorists]. Available at: https://hightech.plus/2018/08/22/globalnoe-poteplenie-izbavit-zemlyu-ot-avtomobilistov2018- 08 -22. htm (accessed 01.05.2023).

3. Khinvud A. Novy`jotchet: issledovanie problem, svyazanny`kh s modifikacziejsolnechnojradiaczii. Novosti OON [New report: A study of the problems associated with the modification of solar radiation. UN news]. Available at:https://www.unep.org/ru/novosti-i-istorii/istoriya/novyy-otchet-issledovanie-problem-svyazannykh-s-modifikaciey-solnechnoy 2023-02-28.htm (accessed 25.03.2023).

4. Khuang K.D. Intellektual`naya sistema avtomobil`noj ventilyaczii na solnechny`kh batareyakh [Intelligent Solar Vehicle Ventilation System], Prikladnaya e`nergetika [Applied Energy], 80, (2), 141-154 (2005).

5. Fayazbakhsh M. A., Bahrami M. Comprehensive modeling of vehicle air conditioningloadsusingheat balance method //SAEtechnicalpaper. – 2013.– Т. 2013.–С. 1507.DOI: 10.4271/2013-01-1507. – URL: https://www.researchgate.net/publication/269250427. (accessed: 01.01.2023).

6. Zima M. Wang M. Kadle P. Bona J. Improving the Fuel Efficiency of mobile A\C Systems with Variable Displacement Compressor //SAEtechnicalpaper. 2014-01-0700. DOI: 10.427/semi.2014.01.0700. – URL: https://www.sae.org/publications/technical-papers/content/2014-01-0700/. (accessed: 01.05.2023).

7. https://alcse.org/the-american-wind-powered-car/ (accessed: 25.03.2023).

8. https://www.zdnet.com/article/chinese-farmer-builds-his-own-wind-powered-car (accessed: 25.03.2023).

Information about authors:

A. Dahham **–** PhD student, Toraighyrov University, 64 Lomov Str., Pavlodar, Kazakhstan.

A. Kassenov – Candidate of Technical Sciences, Associate Professor, Toraighyrov University, 64 Lomov Str., Pavlodar, Kazakhstan.

K. Abishev **–** Candidate of Technical Sciences, Professor, Toraighyrov University, 64 Lomov Str., Pavlodar, Kazakhstan.

А.В. Дахам – докторант, Торайғыров университеті, *Л*омов көш., 64, Павлодар, Қазақстан.

А. Қасенов – Техника ғылымдарының кандидаты, доцент, Торайғыров университеті, *Л*омов көш., 64, Павлодар, Қазақстан.

К. Әбішев – Техника ғылымдарының кандидаты, профессор, Торайғыров университеті, *Л*омов көш., 64, Павлодар, Қазақстан.

А.В. Дахам – докторант, Торайгыров университет, *ул. Л*омова, 64, Павлодар, Казахстан.

А.Ж. Касенов – кандидат технических наук, доцент, Торайгыров университет, *ул. Л*омова, 64, Павлодар, Казахстан.

К.К. Абишев – кандидат технических наук, профессор, Торайгыров университет, *ул. Л*омова, 64, Павлодар, Казахстан.