ТОРАЙҒЫРОВ УНИВЕРСИТЕТІНІҢ
ҒЫЛЫМИ ЖУРНАЛЫ

НАУЧНЫЙ ЖУРНАЛ
ТОРАЙГЫРОВ УНИВЕРСИТЕТА

ҚАЗАҚСТАН ҒЫЛЫМЫ МЕН ТЕХНИКАСЫ

2001 ЖЫЛДАН БАСТАП ШЫҒАДЫ

TORAIGHYROV UNIVERSITY

НАУКА И ТЕХНИКА КАЗАХСТАНА

ИЗДАЕТСЯ С 2001 ГОДА

ISSN 2788-8770

№ 4 (2023)

ПАВЛОДАР

НАУЧНЫЙ ЖУРНАЛ
ТОРАЙГЫРОВ УНИВЕРСИТЕТ
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СВИДЕТЕЛЬСТВО
о постановке на переучет периодического печатного издания,
информационного агенства и сетевого издания
№ KZ51VPY00036165

выдано
Министерством информации и общественного развития
Республики Казахстан

Тематическая направленность
Публикация научных исследований по широкому спектру проблем
в области металлургии, машиностроения, транспорта, строительства,
химической и нефтегазовой инженерии, производства продуктов питания

Подписной индекс – 76129

https://doi.org/10.48081/PWGH3542

Импакт-фактор РИНЦ – 0,210

Импакт-фактор КазБЦ – 0,406

МРНТИ 55.37.33
https://doi.org/10.48081/DCZW7901

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MODELING AND JUSTIFICATION OF THE DESIGN OF WIND TURN BLADES UNDER HIGH WIND SPEED CONDITIONS

The one of main problems that need to addressis study discuss the use renewable energy by justifying the design of the blades to reduce fuel consumption to reduce power by create mechanical power using two or three blade ordinary wind turbine. Each blade length was 0.22 meter and pitch angle of the blade was 2degrees to reach the maximum power from the wind as shows the simulation depending on Beta limit. Solidwork used to design the turbine and to find its moment of inertia and initial parameters. Matlab used to simulate the system equations to find turbine power coefficient depending on ideal pitch angle (Beta) and the tip speed ratio (Lambda), also to findrequired mechanical power to drive different small mechanical devices with power assumed 1400 Watt. As result, the wind turbine gives optimal power required at wind speed is near to 31.5 m /s (113.4 Km/h) and for less wind speed the device could work with less efficiency. Otherwise, high speed produce best efficiency.

Keywords: modeling, design, blades, power, wind turbine, renewable energy, efficiency.

Introduction

The main reasons for increase the atmosphere heat are greenhouse gases, which produced by humans in various ways. Most of them released due to burning fossil fuels in vehicles' engines, factories and generators. [1]

Carbon dioxide (CO_2) is the largest contributor of the warming. While other gases include methane could be come from agriculture, nitrous oxide, gases used for cooling and industrial processes, and deforestation that would otherwise absorb CO_2 [2, 3].

The almost air pollution gases come from the vehicles around the world. Where they produce most of the carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NO_x), and particulates in major urban areas.

The automobile emissions of carbon dioxide are the serious global threat by raise global warming and as a result for many studies, the vehicles emissions depend on many factors such as fuel type, road gradient conditions, the vehicle age and maintenance quality, loads on the engine, as well as the vehicle payload [4, 5].

The renewable energy resources are very important due to the negative effects of the fossil and its gases on the atmosphere and the contemporary problem of the global warming, particularly the wind power can account it free, clean and endless.

For a number of years, renewable energy has been viewed as an economical and environmentally friendly substitute for fossil fuels as a source of power. It has recently been demonstrated that, in many places, power plants employing wind and solar photovoltaic (PV) systems may generate energy more affordably than those using fossil fuels. Globally, it is predicted that more than 26% of renewable energy might be used to generate electricity [6]. This may result in a larger renewable energy capacity than could be achieved by combining nuclear and fossil fuels. The shortcomings of onshore wind turbines, such as wind speed concerns, installation site challenges, and visual issues, have led to the development of floating offshore wind turbines, or FOWTs. The entire worldwide onshore wind turbine capacity was 539,954 MW, while the total global offshore wind turbine capacity was 23,706 MW, according to the 2019 International Renewable Energy Agency (IRENA) Renewable Capacity Statistics and as published in 2018 [7].

Unfortunately, because to the small number of deployments, there is currently little knowledge available about storm-flexible system design. The purpose of the blades rotating on contemporary turbines is to minimise air resistance and/or surface area when wind speeds surpass the expected wind speed. The power that results therefore drops and could even zero. [8]

Regardless of the ideal wind conditions that have been considered in the construction of big turbines, small wind turbines are still designed [9].

As a result, low airspeed and tiny turbine size are employed, which results in low energy generation and poor efficiency [10].

Consequently, a good substitute to survive environmental circumstances would be compact turbines made to endure those conditions. They will also be affordable, eco-friendly, and simple to install and maintain. In rural locations and away from city centres, they might be chosen as independent power generating systems (Singh and Gill 2020) [11].

This study shows ability of use small ordinary wind turbine to generate optimal mechanical power Assumed 1400 watt to drive different small mechanical devices at high wind speed.

Materials and methods

The Turbine Power

It is famous that the general value of power can be define as:

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

In 1919, the German scientist Albert Betz found relation between the power obtained from wind (P_V) and the power produced in the turbine P_{avail} where he found that:

$$P_{avail} = P_v * C_p \tag{2}$$

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

Therefore, he mentioned that the wind turbine cannot convert more than $\frac{16}{27}$ (59.3%) of the wind kinetic energy into necessary mechanical energy required to rotate the rotor. So this ratio called Betz Limit or Betz' Low. The power coefficient (performance coefficient) is conceptualultimate power capacity of any wind turbine modelling is no more than 0.59 and is define as:

$$C_{Pmax} = 0.59 = \frac{P_{avail}}{P_v} = \frac{(1+\frac{V_1}{V_2})(1-(\frac{V_1}{V_2})^2)}{2} \tag{4}$$

The performance coefficient can be account as function of wind speed, so in real use conditions is lower than the Betz Limit with values of 35–45%if ideal design taken into account. In addition, there are some another factors take place in the calculation of the wind power that truly converted to the electric current. Some have negative effects as frictionlike the bearings; gearbox and generator, so only 0.1–0.30 of the wind power are indeed converted.

Therefore, the power coefficient will take place into account these factors and the power from the wind was given by:

$$P_{avail} = \frac{1}{2} * C_P * \rho * S * V^3 \tag{5}$$

For more accuracy, it found that the performance coefficient is function of several factors like ratio between the wind speed and tip speed of blade in addition to number of blades and blade angle Beta. Actually, the C_p value depends on value Beta and Lambda, Where Betaβ is the pitch angle of the blade in degrees, and Lambda λ is the tip speed ratio of the turbine.

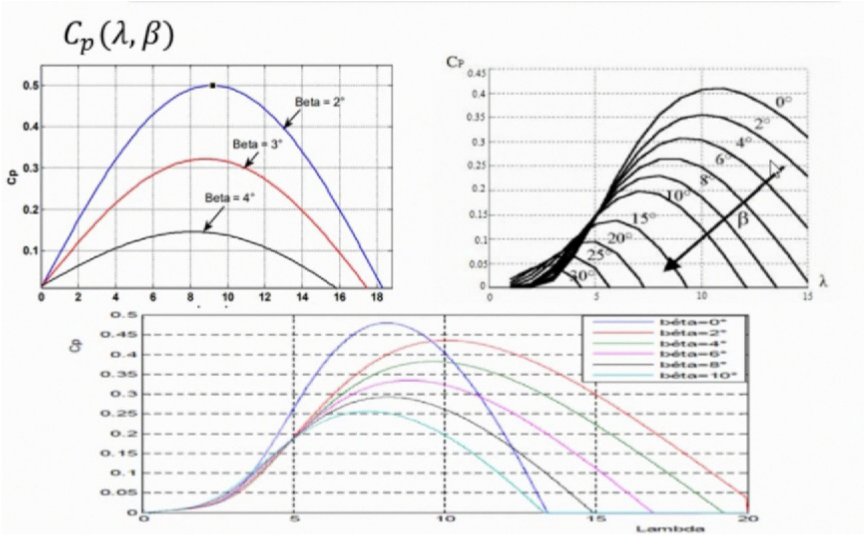

Figure 1 – Cp value depends on value Beta and Lambda

To get maximum power from wind it recommended to design optimal tip speed ratio of wind turbine there are many forms to find the value of, below is the equation that used in this study

$$C_P(\lambda, \beta) = A_1[\left(\left(A_2\frac{1}{\lambda_i}\right) - A_3\beta - A_4\right)e^{A_5\frac{1}{\lambda_i}} + A_6\lambda; \quad (6)$$

$$A_1 = 0.5; A_2 = 116; A_3 = 0.4; A_4 = 5; A_5 = -21; A_6 = 0.0068; \quad \frac{1}{\lambda_i} = \frac{1}{\lambda + 0.08*\beta} - \frac{0.035}{1+\beta^3} \quad (7)$$

Build the turbine essential equations in the Matlab program to calculate the power generated, the value of founded experimentally for many researches using the following equation:

$$\lambda = \frac{\omega_r * Rt}{V} \quad (8)$$

ω_r= blades angular velocity (radian/ sec).

To find the turbine power used the formula

$$P_t = \frac{1}{2} C_p \rho S V^3 \quad (9)$$

The initial parameters of the 2- blade Wind turbine:

To calculate the essential parameters of the ordinary wind turbine used the mass properties in Solidwork packet, where the model made of Aluminum. The diameter of the ordinary wind turbine is 0.5 meter designed to be suitable for the passenger vehicles and can fix in front of the grill, length of the blade is 0.22 meter.

The backside area designed wider than the front area to insure create a pressure difference between front side and backside of the fin where the wind velocity will increase causes low pressure in the backside, which allow wind to push the fin around the rotation axis.

Initial parameters of wind turbine shown below

Mass m= 777.86 grams (0.77787 kg); area S= 64169.80 mm2 (0.06417 m2); volume V= 287035.05 mm3 (0.000287 m3); material density =2710 kg/m3; moment of inertia along the movement axis I=67002280.01 g.mm2 (0.06700228Kg.m2)

Assumptions to modelling the turbine:

There are some assumption to start modelling the turbine in ideal conditions

Consider the blades are similar and homogenous have the same moment of inertia and same parameters

Friction coefficient for the air is zero

Air speed is homogenous when hit the turbine blades area

Results and Discussion

The power consumption by the A/C compressor is 1.46 kW (2H), compressor speed is about 1000rpm, so the torque required =5252*hp/ 1000 = 14Nm and to drive it the ICE required more fuel consumption that means more exhausted gases and more expenses. Therefore, there is a need to create a system based on clean and endless energy. Wind energy is a promising energy and it can mitigate the effects of global warming if the studies presented are properly used. Model of a 2-blade wind turbine Cp represented in Matlab as shown in the figure 3,as results the maximum value of depends on two variables Lambda and beta as in figure 3.

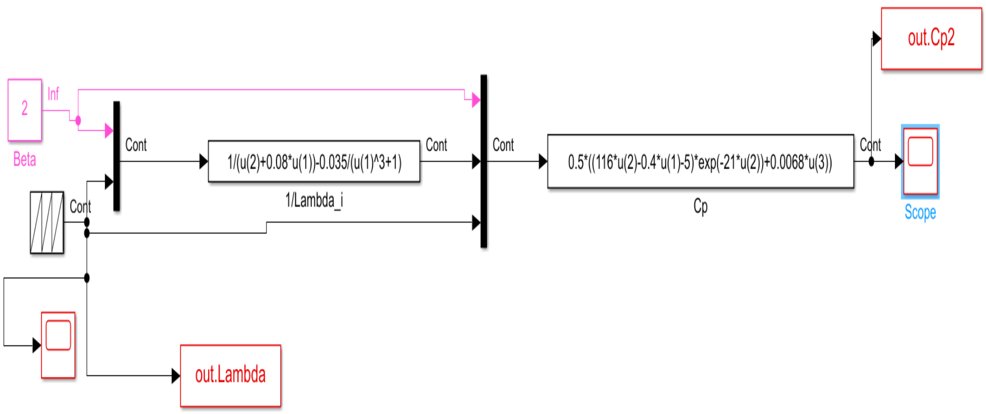

Figure 2 – Turbine equations simulated in MATLAB program

The figure shows the simulation of equation in Matlab program to fine numerically the values of power coefficient when beta varies 2, 4, 6, 8, 10 and 12 degrees when lambda is between 0 and 20

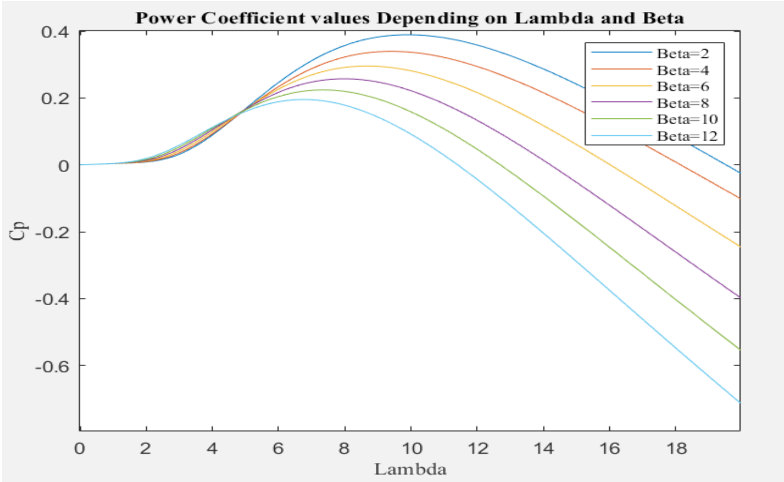

Figure 3 – Values of depending on Lambda and Beta

The figure illustrates that the maximum power can obtain from the wind is when the angle of blade Beta is two when lambda is 10, this power inversely proportional to Beta, therefore this value was selected in this study. Because of that, the study relies on high wind speed according to the vehicle speed.

If the rotor of the wind turbine spins too slowly, most of the wind will pass straight through the gap between the blades, therefore giving it no power. However, if the rotor spins too fast, the blades will be cannot seen and look like a solid wall to the wind. In addition, blades at very high speed can create turbulence as they spin through the air. If the next blade arrives too fast, it actually will hit that turbulent air. So sometimes, it is better to slow down the blades.

Taking into consideration lambda optimal is 10 to get the maximum power and represent the values in Matlab simulation.

The maximum power obtained when the air velocity was 30 m/s (108 Km/h) for first 15 sec was more than 1250 watt then raised to approximately 3000 watt when the wind speed was 40 m/s (144 Km/h)

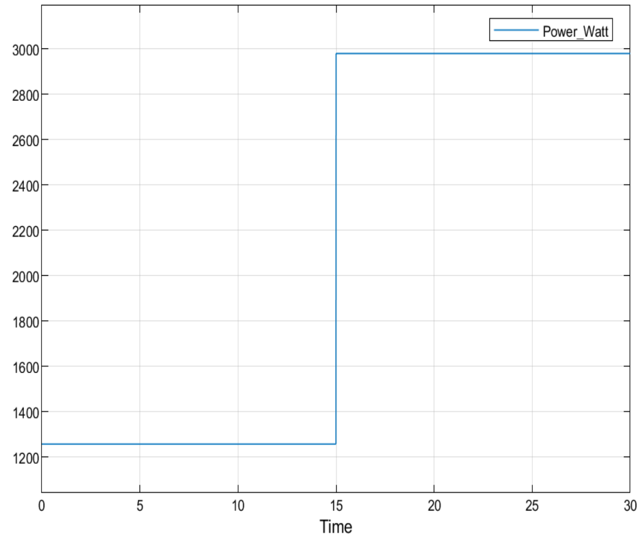

Figure 4 – The range of accepted power related to wind speed

When the wind speed is near to 31.5 m /s (113.4 Km/h), the optimal mechanical power required to drive the compressorcould be obtained as shown below

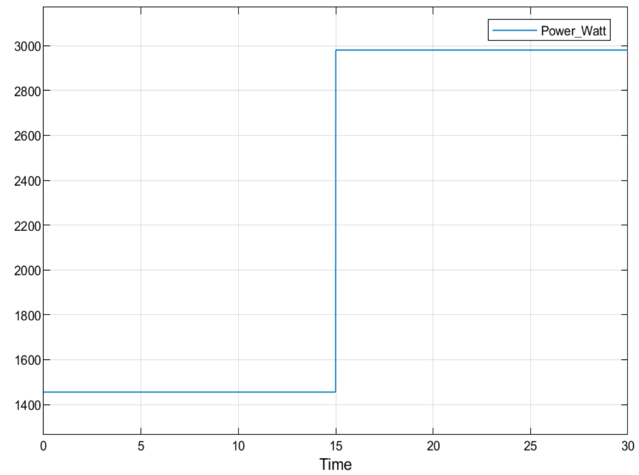

Figure 5 – Optimal power related to wind speed

Conclusion

Designing ordinary wind turbine with small shape and high performance to generate mechanical power for small mechanical devices is possible at wind speed condition. The study showed that optimal power for the small mechanical devicecould be obtainfrom small diameter, 2 – blade wind turbine. The wind turbine gives optimal power required at wind speed is near to 31.5 m /s (113.4 Km/h) and for less wind speed the device could work with less efficiency. However, more efficiency at higher wind speed may obtain.

REFERENCES

1 **Yevtushenko, T. L., Kassenov, A. Z., Mussina, Z. K., Yanyushkin, A. S., Abishev, K. K.** Peakless Rotary Cutter Design for Finish Turning // Lecture Notes in Mechanical Engineering. – 2023. – P. 915–924 doi 10.1007/978-3-031-14125.

2 American National Park Service. From. [Electronic resource]. – https://www.ekoenergy.org/ru.

3 **Kasenov, A. Z., Abishev, K. K., Mazdubay, A. V., Taskarina, A. Z.** Broach for Cylindrical Holes and Slots // Russian Engineering Research. – 2022. – P. 698–700. [Electronic resource]. – doi 10.3103.

4 **Sundar, S.** Effect of automobiles on global warming: A modeling study. Computational Ecology and Software. – 2017. 100 p.

5 **Abishev, K. K., Kasenov, A. Zh., Baltabekova, A. N.** Measuring Devices of Non-Invasive Form for the Study of the Psychophysiological State of the Driver of Motor Vehicles // Mekhatronika, Avtomatizatsiya, Upravlenie. – 2022. – P. 152–157. [Electronic resource]. – doi 10.17587.

6 **Sagar, G., Pathak, D., Gaur, P., & Jain, V.** A Su Do Ku puzzle based shade dispersion for maximum power enhancement of partially shaded hybrid bridge-link-total-cross-tied PV array. Solar Energy. – 2004. – P. 161–180.

7 **Wisatesajja, W., Roynarin, W.** Analysis of Influence of Tilt Angle on Variable-Speed Fixed-Pitch Floating Offshore Wind Turbines for Optimizing Power Coefficient Using Experimental and CFD Models. International Journal of Renewable Energy Development. – 2021. 245 p.

8 **Song, D.; Fan, X.; Yang, J.; Liu, A.; Chen, S.; Joo, Y. H.** Power extraction efficiency optimization of horizontal-axis wind turbines through optimizing control parameters of yaw control systems using an intelligent method. Appl. Energy. – 2018. – P. 267–279.

9 **Karthikeyan, N.; Murugavel, K.K.; Kumar, S.A.; Rajakumar, S.** Review of aerodynamic developments on small horizontal axis wind turbine blade. Renew. Sustain. Energy Rev. 2015, P. 801–822.

10 **Singh, R.K.; Ahmed, M.R.** Blade design and performance testing of a small wind turbine rotor for low wind speed applications. Renew. Energy 2013, P. 812–819.

11 **Singh B and Gill HS.** Wind turbine blade design for low rotational inertia materials at variable speeds with different twisting angle Using Q-Blade. Mater. Today. – 2020. – P. 1666–1670.

Material received on 07.12.23.

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Ресей Федерациясы, Чебоксары қ.
Материал 07.12.23 баспаға түсті.

ЖЕЛДІҢ ЖОҒАРЫ ЖЫЛДАМДЫҚ ЖАҒДАЙЫНДАҒЫ ЖЕЛДІК БҰРУ ПАЛАҚТАРЫНЫҢ ЖОБАСЫН МОДЕЛЬДЕУ ЖӘНЕ НЕГІЗДЕУ

Бұл мақалада екі немесе үш қалақшасы бар кәдімгі жел турбинасы арқылы механикалық қуат қалақтардың дизайнын негіздеу арқылы өндіру арқылы отын шығынын азайту және қуатты азайту үшін жаңартылатын энергияны пайдалануды талқылайтын зерттеу сипатталған. Бета шегіне байланысты модельдеу арқылы көрсетілгендей, желдің максималды қуатына жету үшін әр жүздің ұзындығы 0,22 метр, ал қалақ бұрышы 2 градус. Турбинаны жобалау және оның инерция моментін және бастапқы параметрлерін анықтау үшін Solidwork бағдарламасы пайдаланылды.

Matlab бағдарламасын пайдалану жүйелік теңдеулерді модельдеуге, турбинаның қуат коэффициентін идеал қадам бұрышына (бета) және ұшы қатынасына (лямбда), әртүрлі шағын механикалық құрылғыларды басқаруға арналған механикалық қуаттың функциясы ретінде анықтауға арналған. қуаты 1400 Ватт. Жел турбинасында алынған нәтижелер сипатталған, ол шамамен 31,5 м/с (113,4 км/сағ) жел жылдамдығында қажетті оңтайлы қуатты өндіреді, ал желдің төмен жылдамдығында құрылғы төмен тиімділікпен жұмыс істей алады. Әйтпесе, жоғары жылдамдық максималды тиімділікті қамтамасыз етеді.

Кілтті сөздер: модельдеу, жобалау, қалақшалар, қуат, жел турбинасы, жаңартылатын энергия, тиімділік.

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МОДЕЛИРОВАНИЕ И ОБОСНОВАНИЕ КОНСТРУКЦИИ ЛОПАСТЕЙ ВЕТРОУСТАНОКИ В УСЛОВИЯХ ВЫСОКОЙ СКОРОСТИ ВЕТРА

В данной статье описывается исследование, посвященное обсуждению использования возобновляемых источников энергии для снижения расхода топлива и снижения мощности путем создания механической энергии путём обоснования конструкции лопастей ветряной турбины с двумя или *тремя лопастями – длина каждой лопасти составляет 0,22 метра, а угол наклона лопасти составляет 2 градуса для достижения максимальной мощности ветра, как показывает моделирование в зависимости от предела Бета. Программа Solidwork использовалась для проектирования турбины и определения ее момента инерции и начальных параметров. Использование программы Matlab предназначалось для моделирования системных уравнений, определения коэффициента мощности турбины в зависимости от идеального угла наклона (бета) и передаточного отношения законцовки (лямбда), механической мощности для привода различных небольших механических устройств, с предполагаемой мощностью 1400 Ватт. Описываются полученные результаты ветряной турбины, которая дает оптимальную мощность, необходимую при скорости ветра около 31,5 м/с (113,4 км/ч), а при меньшей скорости ветра устройство может работать с меньшей эффективностью. В противном случае высокая скорость обеспечивает максимальную эффективность.*

Ключевые слова: моделирование, конструкция, лопасти, мощность, ветряная турбина, возобновляемая энергия, КПД.

Теруге 08.12.23 ж. жіберілді. Басуға 29.12.23 ж. қол қойылды.
Электрондық баспа
5,07 Mb RAM
Шартты баспа табағы 17,61 Таралымы 300 дана. Бағасы келісім бойынша.
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