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Optimization of Wind Engine Speed

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ANNOTATION

In this article, the characteristic of the angular velocity of the rotor of a wind unit with a vertical axis of rotation is studied. The optimal values of the angular velocity at which the generated power of the rotor takes the maximum value are determined.

KEYWORDS: *Wind unit, rotor, angular rotation, angular velocity, power, optimal values, number of wings, wind speed.*

Below we will check how the angular velocity of rotation of the rotor is related to its generating capacity, based on the rules of the theory of mechanisms and theoretical mechanics, and draw conclusions about the rational values of the angular velocity that provide the maximum power value. As you know, the production capacity of the rotor of a wind turbine with a vertical axis is equal to

$$P_1 = \frac{1}{24} \cdot c_x \cdot \rho \cdot h \cdot \ell^2 \cdot (6 \cdot \upsilon^2 \cdot (1-k^2) \cdot \omega \cdot \mathrm{Sin}^2\varphi - 8 \cdot \upsilon \cdot \omega^2 \cdot \ell \cdot (1-k^3) \cdot \mathrm{Sin}^4\varphi + 3 \cdot \omega^3 \cdot \ell^2 \cdot \mathrm{Sin}^6\varphi \cdot (1-k^4)) \quad (1)$$

$$P_2 = \frac{1}{24} \cdot c_x \cdot \rho \cdot h \cdot \omega \cdot \ell^2 \cdot (6 \cdot \upsilon^2 \cdot \omega \cdot (\mathrm{Sin}^2(\varphi+\theta) - \mathrm{Sin}^2\varphi) - \mathrm{Sin}^3\varphi) \cdot \mathrm{Sin}(\varphi+\theta) + 8 \cdot \omega^2 \cdot \upsilon \cdot \ell \cdot (\mathrm{Sin}^3(\varphi+\theta) \cdot 3 \cdot \omega^3 \cdot \ell^2 \cdot (\mathrm{Sin}^4(\varphi+\theta) - \mathrm{Sin}^4\varphi) \cdot \mathrm{Sin}^2(\varphi+\theta)) \quad (2)$$

is expressed by equations.

In this case, P_1-active power, M_2-partially active wing power, c_x - forehead resistance of the wing, ρ - wing density, h - wing height, ℓ - wing radius, υ - wind speed, φ - angle between wing radius and wind speed vector, θ - angle between the wings, ω - rotor angular speed.

First of all, in the system of equations (1), we simplify expressions that do not depend on angular velocity. To do this, we enter the following designations:

$$B1 = \frac{1}{24}\rho \cdot c_x \cdot h \cdot \ell^2 \qquad B2 = 6 \cdot \upsilon^2 \cdot \sin^2\varphi \cdot (1-k^2)$$

$$B3 = \upsilon \cdot \ell \cdot \left(\sin^2\varphi + 2\cos 2\varphi \cdot \left(\sin^2\varphi + \frac{3}{2}\right) - 3\right) \cdot (1-k^3)$$

$$B4 = -\frac{1}{16} \cdot \ell^2 \cdot \left((8 \cdot \sin^2\varphi - 5) \cdot \sin^2 2\varphi + 2 \cdot \cos 2\varphi \cdot \left(4\sin^4\varphi + 5\sin^2\varphi + \frac{15}{2}\right) - 15\right) \cdot (1-k^4)$$

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$$B7=\ell^2\cdot\Bigg(\sin^2(\varphi+\theta)\cdot\left(\frac{1}{2}\sin^2(\varphi+\theta)+\frac{5}{4}\cos 2(\varphi+\theta)+\sin 4(\varphi+\theta)\right)+\frac{15}{4}\cos(\varphi+\theta)+\frac{5}{4}\sin^2 2(\varphi+\theta)+$$
$$2\cos 2\varphi\cdot\cos^2\theta\cdot\left(\sin^4\varphi+\frac{1}{4}\cdot\sin^2\varphi+2\right)+\sin^2 2\varphi\cdot\cos^2\theta\left(2\sin^2\varphi+\frac{1}{4}\right)+3\cdot\sin\varphi\cdot\sin 2\theta\cdot\Big(\sin 2(\varphi+\theta)-$$
$$2\sin^4\varphi-\sin^3\varphi\cdot\sin 2\varphi\Big)+\frac{1}{4}\cdot(15\cdot\cos\theta+18)\Bigg)$$

$$B5=-3\cdot\upsilon^2\cdot\left(\sin^2\varphi+\cos 2(\varphi+\theta)+1\right)$$

$$B6=\upsilon\cdot\ell\cdot\Big(\cos 2\cdot(\varphi+\theta)\cdot(2\sin^2(\varphi+\theta)+3)\left(\sin^2(\varphi+\theta)+(2\cos^2\varphi+1)\cdot\cos\varphi\right)\cdot\cos\theta+$$
$$3\cdot(1-\cos\varphi)+8\cdot\sin^3\varphi\cdot\cos\varphi\cdot\sin\theta\Big)$$

Then, according to the equations of designation and the two conditions of calculation, the power equation looks as simple as:

$P_1 = B1\cdot B2\cdot\omega+B1\cdot B3\cdot\omega^2+B1\cdot B4\cdot\omega^3$ **condition 1**

$P_2 = B1\cdot B5\cdot\omega+B1\cdot B6\cdot\omega^2+B1\cdot B7\cdot\omega^3$ condition 2 (3)

Since the power value is not equal to zero at all values of the angular velocity except zero, we are limited to determining its extremum states. (3) from the equality we define the first order derivative of the case by the case and write it down with a short transformation, equating it to zero:

$3\cdot B4\cdot\omega^2+2\cdot B3\cdot\omega+B2=0$ condition 1

$3\cdot B7\cdot\omega^2+2\cdot B6\cdot\omega+B5=0$ condition2 (4)

Taking into account the solution of the proposed quadratic equations, its two conditions, we write the expression of the rotor angular velocity with a short change and get the equations of the following appearance:

by condition 1,

$$\omega_1^-=\frac{-B3-\sqrt{B3^2-3\cdot B4\cdot B2}}{3\cdot B4}\qquad \omega_2^+=\frac{-B3+\sqrt{B3^2-3\cdot B4\cdot B2}}{3\cdot B4}\qquad (5)$$

by condition 2,

$$\omega_1^-=\frac{-B6-\sqrt{B6^2-3\cdot B6\cdot B5}}{3\cdot B7}\qquad \omega_2^+=\frac{-B6+\sqrt{B6^2-3\cdot B6\cdot B5}}{3\cdot B7}\qquad (6)$$

If there are such points, then this can only happen if the discriminant of equality (5) and (6) is greater than or equal to zero:

$D = B3^2 - 3\cdot B4\cdot B2 > 0$ by condition 1,

$D = B6^2 - 3\cdot B6\cdot B5 > 0$ by condition 2, (7)

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Computer Helpa verification shows that the discriminant value receives constant positive values. This indicates that the number of extremum points in it is two. If we take into account that the power value has a constant positive value, then first, after the maximum, we will have a graph representing the minimum value (assuming that the graph, first, will reach the minimum value, then from the maximum value of which the number of extremums is two, the graph line must cross the negative limit of the And this does not coincide with the essence of the matter. The next bastards confirm this. In the calculations (5), (6) we use the following two equations of expressions:

$$\omega_{рац.1} = \omega_1^- = \frac{-B3 - \sqrt{B3^2 - 3 \cdot B4 \cdot B2}}{3 \cdot B4}$$

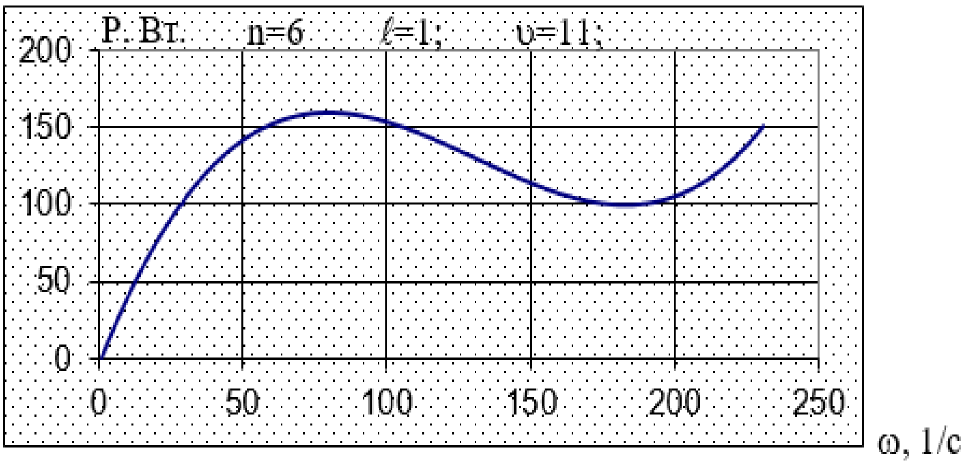
$$\omega_{рац.2} = \omega_1^- = \frac{-B6 - \sqrt{B6^2 - 3 \cdot B6 \cdot B5}}{3 \cdot B7} \qquad (8)$$

We believe that their value is contrary to logic, since the value of the remaining two equations has negative indicators.

The appearance of one of the special cases of the graph, which represents this power value, is presented in figure 1. From the form, it can be concluded that the rotor angle corresponds to each value of the headboard, the only maximum value of power. Then the rational mean of the angular velocity can be determined by the equation of the following view:

$$\omega_{рац.ур.} = \frac{1}{360} \sum_{\varphi=0}^{360} \left(\omega_{рац}\right)_i \qquad (9)$$

In Form 2 n, ℓ, υ the average angular velocity of the rotor $\omega_{рац.ур.}$ corresponds to some obtained values of its values. Since n, ℓ values are invariant in our structure, it can be deduced that a change in wind speed υ leads to a change in speed $\omega_{роц.\ ур.}$ this change is not optimal for the movement of the working body. This summarized aggregate construction necessitates the design of a new mechanism of the automatic control system.



Form 1: Generator shaft angle of power value

dependence on speed: in this $\varphi_{ротор}=0$

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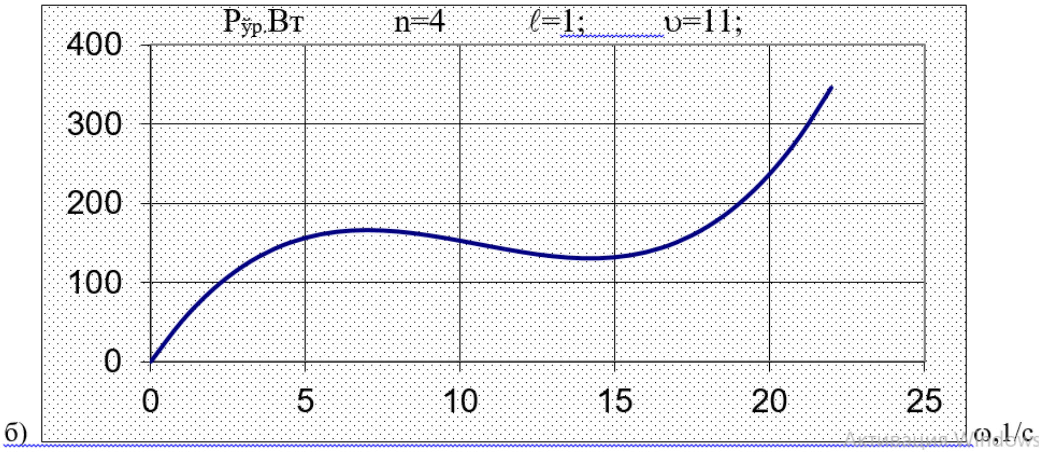
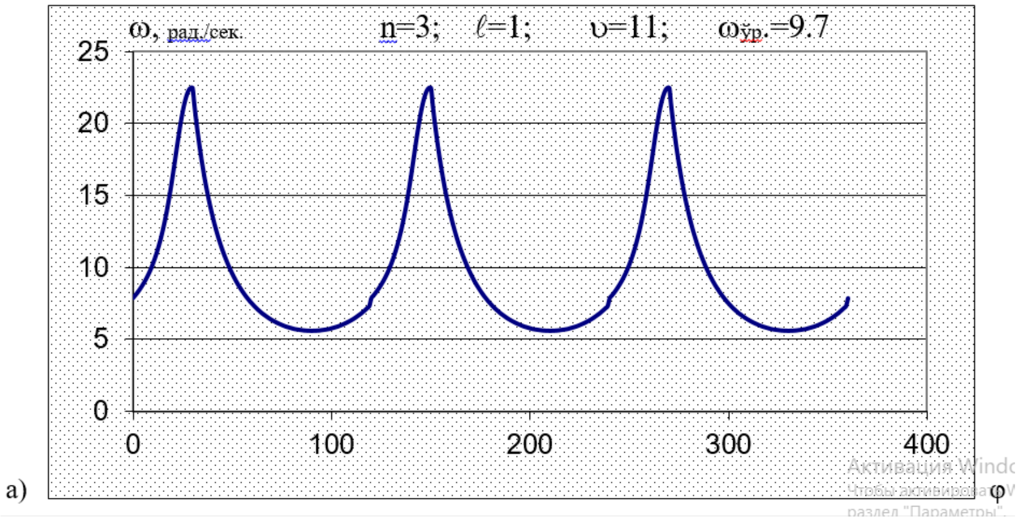
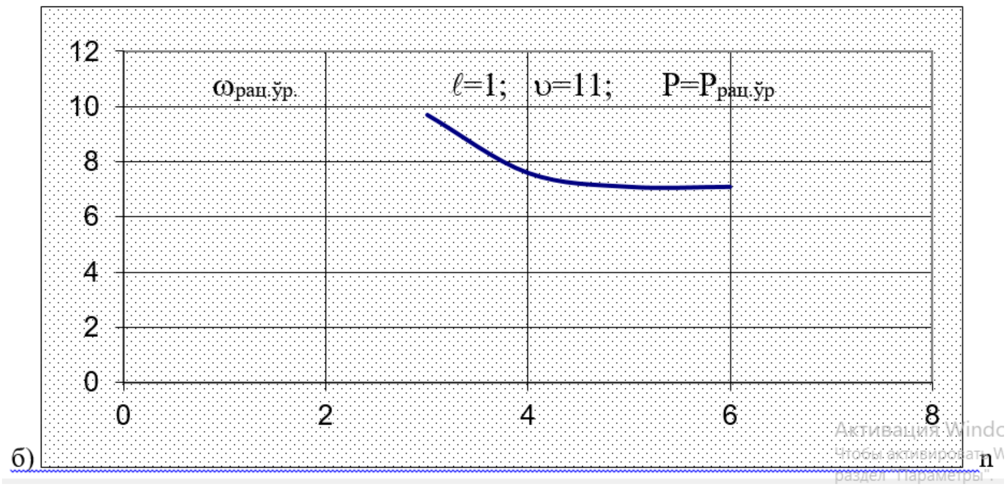
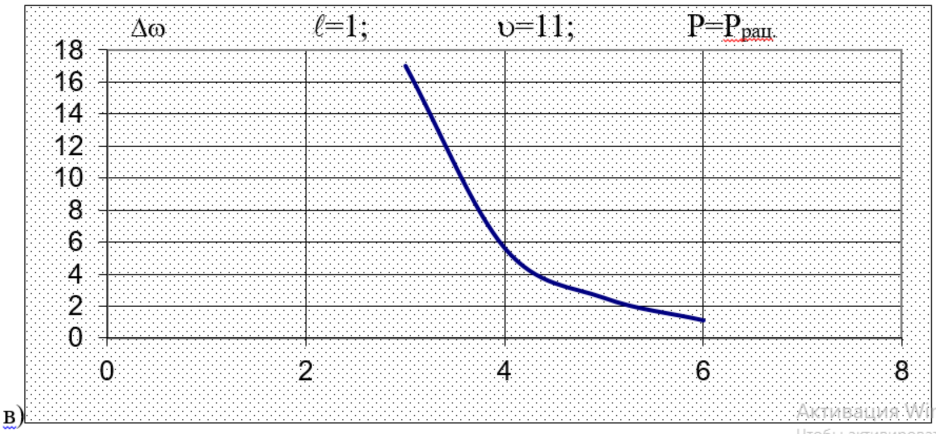
The result of the calculations carried out according to the system of equations confirmed that the value of 1 ensures that the power value is maximum. According to them, graphs representing $\omega_{рац.}=f(\varphi)$, $\omega_{рац.ўр.}=f(n)$, $\Delta\omega_{рац.ўр.}=f(n)$ 4 links are presented in form 3.



Form 2. To the rotor angular velocity of the power value graph showing the dependence: in this $\varphi_{ротор}=0$







Form 3. The rational average angle of the rotor description of speed

Conclusions: (2) let us draw the following conclusions based on the graphs built in the process of making a mathematical analysis of the system of equations in $\omega = f$ (n, ℓ , h, υ, φ,) dependencies -

- Rotor angular velocity is the most basic factor determining its generating capacity. An important role in this is played by the number of revolutions per unit of time.
- To each value of the angle of rotation, the value of the single rotor angle speed is suitable, which ensures that the power is maximum (fig.). This is why the value of the average angular velocity of the angle of rotation in one period interval is proposed (expression 9).
- There is only one average value of the angular velocity, which ensures that the generating capacity value of the wind aggregate rotor is maximum when its geometric parameters and wind speed are unchanged (Figure 2).
- To each value of the angle of rotation of the Rotor wing, the angle corresponds to only one value of the speed, and it has a periodic character (form 3a)
- An increase in the number of wings from 3 to 6 Increases the value of the rational angular velocity by 9.7 1/sec. from 6,7 1 / sec. reduces up to (form 3b).
- In the Real working state of the aggregate, the wind speed is constantly changing, which leads to a change in the rotor angular velocity. As a result, the amount of energy that the rotor generates changes. The working body is excluded from the state of the rational. These hulos set the sour condition by changing the useful resistance of the working body as necessary ($M_{хар.}=f(\upsilon)$) and in this way helps to keep the working shaft in an optimal position, the rotor stabilizes the state of maximum power generation.

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