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ISSN 1727-6209
International Journal of Computing

DESIGN OF WORK SLOW WIND-WHEEL POWER PLANT WITH PADDLES OF PERMANENT TYPE AFTER ITS RADIUS

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Abstract: *The task of optimizing velocity rotation of low-speed wind-wheel and optimal profile of its paddles according to criterion at most possible selection of power from weak air flow is set and worked out in the article. The method of determination the necessary angles of own turn of paddles and axis of rotation of wide-wheel shaft with higher speed of air flow with the aim of support nominal capacity of wide-power installation is suggested.*

Keywords: *low-speed wind-wheel, optimal profile of paddles.*

1. INTRODUCTION

Nowadays the wind power has its own established traditions in the development of energetics [1]. Large farms, which are spreading now on the territory of Ukraine, are in a growing need for cheap wind-driven electric sets (WDS) of maximum unit power within 3-6 kW.

As a rule, the maximum project power of WDS, the size of the wind-wheel (WW), the geometry of its paddles are determined for a specific, standard for certain regions of the globe, velocity of the air flow (AF). Thus, for the northern regions the value of this velocity is generally equalled to 12 m/s, which corresponds to 6 numbers on the Beaufort scale. In the countries of continental Europe and the USA the standard value of the AF velocity is settled on 7,5 m/s, which corresponds to the AF power of 4 numbers on the Beaufort scale.

The standard velocity value of the AF is related to the value of the average yearly AF velocities in a given region. For that reason, from the perspective of the longstanding meteorological observations on the terrains of Ukraine, it seems justified to assume that the sizes of the WW, the geometry of its paddles and the project power of the WDS, which are expected to be exploited within its territory, have to be determined for the AF velocities of 3-5 m/s, and these velocities have to be accepted as standard for most regions in Ukraine. They correspond to the 3-numbered power of the AF on the Beaufort scale.

Low velocities of the AF don't permit an effective functioning of the paddles, the profile of which is based on the effects of aerodynamics. Therefore in cases like this it seems expedient to use the paddles with the profile based on the effects of sail and turn of vector of the AF velocity at its immediate contact with the working surface of the paddle. In order to create a leading power the paddle should not rotate faster than the AF, which blows onto its elementary surfaces. Since the AF velocity is low, the wind-wheel used for such AFs is called a low-speed wind-wheel (LWW).

The research papers [3-5] analyze the work of the LWW with a rectilinear generatrix of the paddle's working surface. The generatrix's rectilinearity facilitates to a great extent the technology of constructing the paddle, which has a considerable impact on the worth ratio of the settled WDS capacity unit. However, this impact decreases for the WDS with low capacities.

Among other things, it has been assumed in the research papers [3-5] that a WW has a great number of paddles (24 and more). It enabled the authors of these papers to define the optimal orientation of the paddle's elementary surface just at the place of the location of its flap, maintaining this orientation along the whole rectilinear width of the paddle's element. Moreover, the spacing intervals between the points of the distinguished elementary stria of the paddle and the rotation axis of the WW were only slightly different, since the quantity of the paddles was large. When the quantity of the WW paddles decreases to 9-12, these differences become more conspicuous. For that reason, the ultimate parts of the paddle with a rectilinear generatrix of its working surface have a non-optimal orientation around the radius.

2. MAIN PART

In order to increase the coefficient of efficiency of the WW there has been suggested a paddle [6], in which the optimal orientation of its elements is maintained not only at the place of the location of its flap (fig.1), but also on the whole circle of a random intermediate radius of the WW (fig.2).

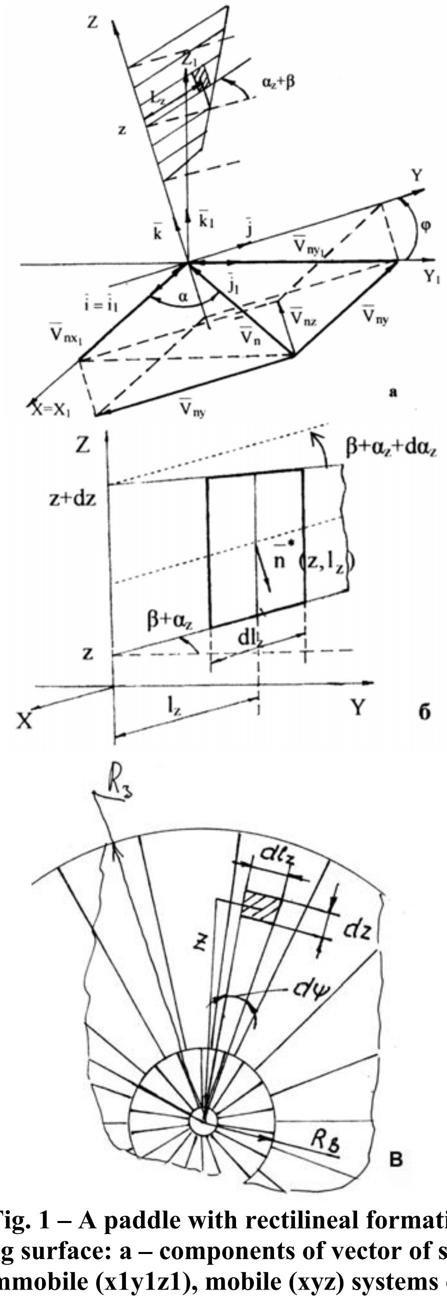

Fig. 1 – A paddle with rectilineal formative it working surface: a – components of vector of speed in immobile (x1y1z1), mobile (xyz) systems of coordinates and elementary plane of paddle; б – an orientation of elementary plane in space; в – a frontal type of elementary plane.

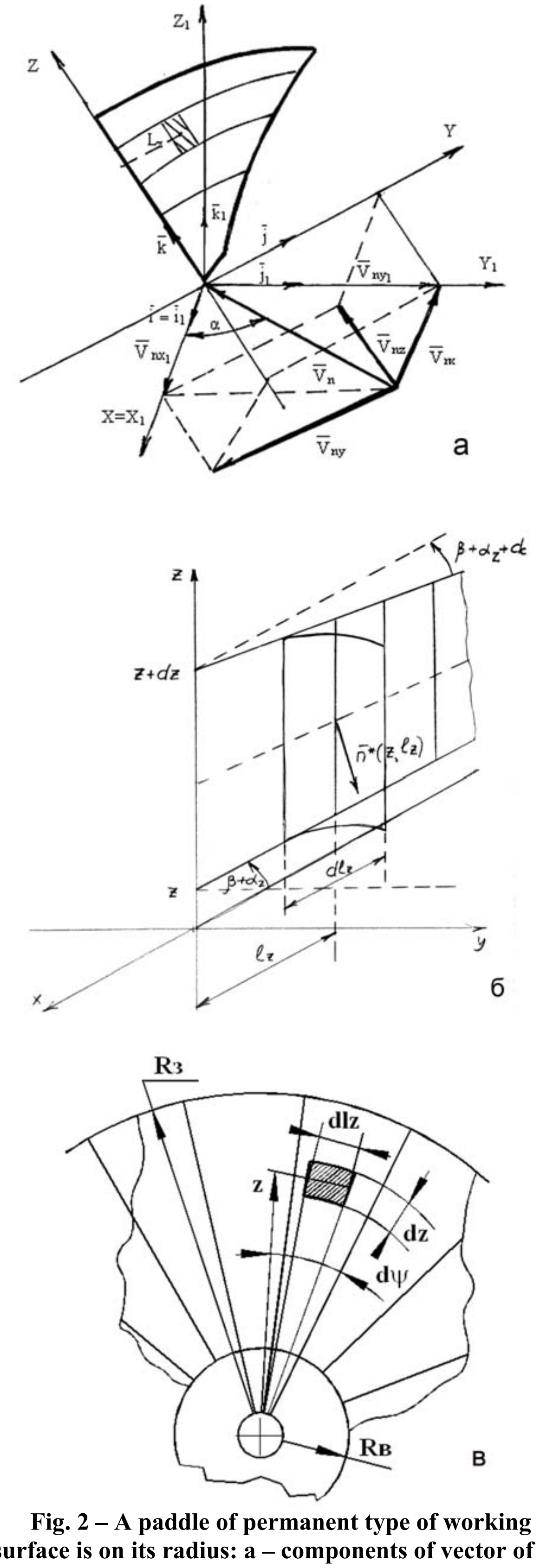

Fig. 2 – A paddle of permanent type of working surface is on its radius: a – components of vector of speed in immobile (x1y1z1), mobile (xyz) systems of coordinates and elementary area of paddle; б – an orientation of elementary area in space; в – a frontal type of elementary area.

It looks like this:

$$d^2 N_{z,l_z} = A_1 \frac{d\varphi}{dt} z \cos\alpha_{z,l_z} V_n \left(A_2 + A_3 l_z \frac{d\alpha_z}{dz} \right).$$

$$d^2 N_{z,l_z} = A_1 \frac{d\varphi}{dt} z \cos\alpha_{z,l_z} V_n \left(A_2 + A_3 l_z \frac{d\alpha_z}{dz} \right), \quad (1)$$

where $A_1 = \rho_n \sin(\alpha_z + \beta)$; $A_2 = \cos\alpha\cos(\alpha_z + \beta) + \sin\alpha\cos\varphi\sin(\alpha_z + \beta)$; $A_3 = \sin\alpha\sin\varphi$; ρ_n, V_n – the specific weight and horizontal velocity of the air flow, which blows onto the paddle; α_z – the angle of the paddle's profile at the distance of z from the axis of the WW rotation; $\frac{d\alpha_z}{dz}$ – the velocity of changing the profile's angle with changing the distance to the axis of the WW rotation; $\beta, \frac{d\beta}{dt}$ – the angle and velocity of the paddle's rotation itself around its own axis of rotation (around the flap); α – the angle between the velocity vector of the air flow and the rotation axis of the WW; $\varphi, \frac{d\varphi}{dt}$ – the angle of rotation and the angular velocity of the WW rotation; l_z –the distance between the axis of the paddle's rotation around itself and the centre of the distinguished part of the elementary surface $dz \cdot dl_z$; α_{z,l_z} – the angle between the normal to the distinguished part of the paddle of the elementary surface $dz \cdot dl_z$ and the horizontal surface.

The power which the WW withdraws from the air flow in general is equal to:

$$N = 2\pi\rho_n \int_{R_B}^{R_3} z^2 \frac{d\varphi}{dt} \sin\alpha_z V_n \cos\alpha_z \cdot \cdot \left(V_n \cos\alpha_z - \frac{d\varphi}{dt} z \sin\alpha_z \right) dz, \quad (2)$$

where RB, R3 are the internal and external radii of the WW.

The problem of the mechanics as to optimizing the rotation velocity of the LWW and the profile angel of its paddles according to the criterion of the maximum possible selection of power out of the low AFs was being solved as a mathematical problem of searching the extremum of the functional (2), which contains the unknown parameter $\frac{d\varphi}{dt}$.

Substituting the function of the optimal angle α_z^{on} of the paddle's profile in (2), we get the maximum meaning of the functional, i.e. the maximum meaning of the power N^{on}, which can be withdrawn by the WW with the paddles of the most optimal profile's angle α_z^{on}:

$$N^{on} = 2\pi\rho_n \int_{R_B}^{R_3} z^2 \frac{d\varphi}{dt} \sin\alpha_z^{on} V_n \cos\alpha_z^{on} \left(V_n \cos\alpha_z^{on} - \frac{d\varphi}{dt} z \sin\alpha_z^{on} \right) dz. \quad (3)$$

In order to define the optimal ω_k^{on} angular velocity $\frac{d\varphi}{dt}$ of the WW rotation it is necessary to equate to zero the partial derivative from N^{on} at $\frac{d\varphi}{dt}$, that is:

$$\frac{\partial N^{on}}{\partial \omega_k^{on}} = 0, \quad (4)$$

3. CONCLUSION

In order to verify the rightfulness of the analytic methods and the correctness of the obtained mathematical dependences there has been elaborated a nine-paddled mock-up of the WDS and it was tried in an aerodynamic pipe of the Lviv Polytechnic National University at the department of heat and gas supplies and ventilation under supervision of prof. Voznjak O.T. The results of the experiments proved the rightfulness of the suggested assumptions and a sufficient for the practice needs accurateness of the results obtained analytically.

4. REFERENCES

[1] John Twidell, Tony Weir. Renewable Energy Resources. Translation from English under. V.A. Korobkova. M. Energoatomizdat, 1990, 392 p. [in Russian]

[2] Statutory broker on hydrometeorology. Ukrainian republican management on hydrometeorology. Scientifically the applied reference book on the climate of the USSR. Series 3. Long-term information. Parts of 1- 6. 10 Edition. Ukrainian SSR. Book 1. Leningrad. Gidprometeoizdat 1990, 420 p. [in Russian]

[3] I.S. Lozovyj, M.B. Kudlyk. A design of work of the linear profiled paddle of wind-wheel is with the horizontal axis of rotation. Collection of labours of the IV International scientifically

– practical conference “Modern problems of geometrical design”, part of September, 2. 4-6, 1997 Melitopol’, 1997, p. 96-97. [in Ukrainian]

[4] I.S. Lozovyj, M.B. Kudlyk. Speed of rotation of slow wind-wheel and type of his paddle is optimum after the criterion of maximal power takeoff from weak blasts. Announcer Lviv Polytechnic National University: Dynamic, durability and design of machines and devices. N434, 2001, p.92-96. [in Ukrainian]

[5] M.B. Kudlyk, I.S. Lozovyj. Influence of type of paddle of slow wind-wheel, orientation and speed of his rotation on a selection powers them from a blast. Announcer Lviv Polytechnic National University: Heat engineering, engineering of environment, automation. N 452, 2002, p.269-273. [in Ukrainian]

[6] Zinko R.V., Kudlyk M.B., Kruts T.I., Lozovyj I.S. Design of work of the wind-power installation with the paddle of permanent type on the radius of wind-wheel. Second the International scientific and technical conference “Computer sciences and information technologies” (CSIT-2008). on September, 25 – 27, 2008 Lviv Polytechnic National University. p. 269-272. [in Ukrainian]

[7] Young L.C. Lectures on the calculus of variations and optimal control theory Publishing house the “World”, Moscow, 1974. 488 p. [in Russian]