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RELATIONSHIP OF WATER WHEEL PARAMETERS

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Using the possibilities of renewable energy sources, especially the problem of obtaining electricity using low-pressure water sources, has become an urgent problem today. Because it is they who make up the majority and are found very widely. Places with a water pressure of 4-5 meters are rare. The main part of water sources (channels, collectors, etc.) has a depth of 0.5-3 meters [1]. In rural and mountainous areas, there are many places where you can create a pressure of up to 3 meters on existing water sources. Previously, water wheels were used for irrigation. Today it is important not only to irrigate the fields, but also to receive electricity for remote users, i.e. use these water sources as a source of energy (wheel horizontally or vertically) [2,3].

The paper [4] considers the theoretical aspects of the operation of a water wheel, taking into account the aspects of using water wheels at low water flow rates and low pressures, as well as the need for mathematical calculation of the design of water wheels. It is proposed that an accurate calculation will reduce turbulence and maximize the power take-off of the water flow, thereby increasing the moment of force applied to the wheel axle.

If we pay attention to the hydrological parameters and the location of water sources flowing through the regions, then the shape of the perimeter and the cross-sectional surface of the water flow in canals, rivers and irrigation systems is rectangular. For the use of a water wheel in these sources, the place of their installation in the channel plays an important role [5]. Because the speed of water in such water sources is different at different points along the width and depth of the source.

At small angles of inclination, the kinetic energy of the water flow does not change, its speed is constant. Its potential energy is converted into thermal energy, i.e. dissipates. The result obtained refers to shallow low-velocity water sources and may not be relevant for deep-sea sources with high velocities.

$$\operatorname{div} \vec{\vartheta} = 0$$

To simplify the problem, let the water flow regime be laminar and the velocity be low. This condition makes it possible not to take into account the effect of eddy currents generated behind the water wheel during its operation.

Then, with parallel motion directed along the x axis, the speeds $\upsilon = 0$ and $\omega = 0$. It follows from the non-uniformity $\frac{\partial u}{\partial x} = 0$ that for all x, therefore, i.e. is a function only of z. Because:

$$\frac{\partial h}{\partial x} = 0; \quad \frac{\partial h}{\partial y} = 0; \quad \frac{\partial h}{\partial z} = 1; \qquad (1)$$

Then, under these conditions, the equations of motion (1) take the form:

$$-\frac{1}{\rho}\frac{\partial P}{\partial x} + \frac{\eta}{\rho}\frac{\partial^2 u}{\partial y^2} = 0;$$

$$-g - \frac{1}{\rho}\frac{\partial P}{\partial z} = 0; \qquad (2)$$

Integrating equation (2) with respect to pressure, we obtain:

$$P = \rho g z + f(x) \qquad (3)$$

$$\frac{\partial^2 u}{\partial x^2} = \frac{1}{\eta}\frac{\partial P}{\partial x} \qquad (4)$$

Integrating (4) over y, we obtain:

$$u = \frac{y^2}{2\eta}\frac{dP}{dx} + C_1 y + C_2 \qquad (5)$$

At the same time, using the boundary conditions $u = 0$ at $y = 0$, we determine that $C_2 = 0$ at $y = 2b_1$, $C_1 = \frac{dP}{dx} b_1$.

Here b1=b/2, therefore:

$$u = \frac{y^2}{2\eta}\frac{dP}{dx} - \frac{b_1 y}{\eta}\frac{dP}{dx} \qquad (6)$$

If , $u = 0$ a parallel jet flow is obtained and the velocity distribution is parabolic:

$$\frac{\partial u}{\partial x} = \frac{y}{\eta}\frac{dP}{dx} - \frac{b_1}{\eta}\frac{dP}{dx} = 0$$

The maximum speed value is reached $y = 2b_1$ at:

$$u_{max} = -\frac{b_1^2}{\eta}\frac{dP}{dx} \qquad (7)$$

In the case of fluid movement between parallel walls, pressure changes along x:

$$\frac{dp}{dx} = \frac{p_0 - p_L}{L} = \frac{3\eta Q}{2bh^3} \qquad (8)$$

$$u_{max} = \frac{b_1^2}{2\eta}\frac{3\eta Q}{2bh^3} = \frac{3bQ}{16h^3} \qquad (9)$$

Average flow rate: $V = \frac{u_{max}}{2}$;

As a result, we get the Poiseuille equation:

$$u = \frac{u_0 z}{h}; \qquad (10)$$

We determine the energy parameters of the impeller. To do this, we assume that the speed u0 of the flow of water running on the water wheel, installed on the width of the channel on the water surface, is determined experimentally. Integrating formula (10), we obtain the necessary expression for the levels of water impact Δhi and the corresponding average velocities ϑ_1, ϑ_2, ..., ϑ_n of the water flow acting on the surface of this shovel depending on the immersion depth of each shovel (Fig. 1):

$$\vartheta_n = \frac{1}{b}\int_{y_{n-1}}^{y_n}\frac{u_0 z}{h}dz = \frac{u_0}{2bh}\left(y_n^2 - y_{n-1}^2\right), \quad y_n = \sum_{i=1}^{n} h_i \ , \ h_n = 2R_1 Sin\frac{\alpha}{2}\cdot Sin\left(\frac{2n-1}{2}\right)\alpha \qquad (11)$$

The head indicated by the average velocity of the water flow on the surface of the blades. Therefore, we find the projections of the corresponding velocities on the normal of the blade surface $\vartheta_{1\perp}$, $\vartheta_{2\perp}$, ..., $\vartheta_{n\perp}$:

$$\vartheta_{n\perp} = \vartheta_n Cos(n-1)\alpha \qquad (12)$$

Using expression (14), we find the dynamic pressure of the water flow in the direction normal to the blades as follows:

$$P_n = \frac{\rho}{2}\vartheta_n^2 Cos^2(n-1)\alpha \qquad (13)$$

Based on formula (13), one can find the corresponding force Fi acting on the shovel, each of which has a width b according to the following formula: i=1, 2, …, n

$$F_i = h_i P_i \cdot b \qquad (14)$$

The center of water pressure exerted by the water flow on the blades is at different distances from the center of the water wheel, depending on the degree of immersion of the blade. The distances from these pressure centers to the center of the water

wheel shaft constitute the power arm of each blade. According to the indicated points, we determine the power shoulder of each blade:

$$r_{1c} = R_1 - \frac{h_1}{2}; \quad r_{2c} = R_1 - \frac{h_2}{2Cos\alpha};$$
$$r_{3c} = R_1 - \frac{\ell}{2}; \quad r_{4c} = R_1 - \frac{[H_0 - (h_1 + h_2 + h_3)]}{2Cos3\alpha} \qquad (15)$$

Based on the above, you can find the moments of forces acting on the water wheel:

$$M_n = F_n \left[R_1 - \frac{\left(H_0 - \sum_{i=1}^{n-1} h_i \right)}{2Cos(n-1)\alpha} \right] \qquad (16)$$

$$F_n = \rho R_1 b \vartheta^2 \cdot Sin\frac{\alpha}{2} \cdot Sin\frac{(2n-1)\alpha}{2} \cdot Cos^2(n-1)\alpha. \qquad (17)$$

In order to determine the energy parameters of the wheel based on the formulas obtained above, it is necessary to calculate the total moment of inertia of the impeller. Using the Huygens-Steiner theorem consisting of the algebraic sum of the moments of forces arising in all the blades :

$$M_t = \sum_{i=1}^{n} M_i \qquad (18)$$

$$I_t = \sum I_k + \sum I_{таянч} + \sum I_{halqa}; \quad \omega = \frac{M_t}{I_t}$$

$$E = \frac{I_t \omega^2}{2} = \frac{M_t \omega}{2}; \quad E_W = \frac{m\vartheta_t^2}{2}; \quad \eta = \frac{E}{E_W} 100\% \qquad (19)$$

With the help of formulas (16)-(18) through its geometric parameters, it is possible to determine the desired energy parameters of the water wheel.

Based on the results obtained, the optimal design parameters were determined by changing the dimensions of the water wheels in accordance with the water flow rate. By substituting the obtained formulas (18)-(19) for the torque and forces in (19), it is possible to determine the optimal value of the radius of the water wheel from the obtained expression for the torque to determine the efficiency of the wheel.

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