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PARAMETERS OF THE ANTI-ROTOR HYDRO UNIT WITH DIFFERENT TYPES OF IMPELLER

Bozarov Oybek Odilovich,
Tashkent University of Technology, PhD, Doctoral Candidate (DSc),
Tel: (94) 278 81 70. E-mail: obozarov7@inbox.ru

It is known that the main part of the existing rivers, canals and other hydro sources have a low pressure. Today, almost all over the world, the use of this hydropower potential for the purpose of generating electricity is of particular interest and is considered an urgent task [1].

If we pay attention to active hydraulic turbines, which are designed to work in a low-pressure watercourse, we can see their positive and negative sides. In [2], a catamaran-type floating hydraulic device was developed, which operates unstably in response to changes in water flow. In [3], bladed gearboxes independently transmit motion through gears to a shaft mounted vertically or horizontally. They are large in size, work unstably when the amount of water flow changes. In [4], active hydraulic turbines were developed, consisting of water wheels operating at low water flow and low pressure and at a head of 2-3 meters, and the devices are large. The existing designs of jet turbines (radial-axial, propeller, rotary-blade, two-blade) are characterized by the fact that they operate effectively at heads of more than 4-5 m. In work [5], the shortcomings of work [6] were eliminated by installing an internal guide device in the impeller. The nozzle jet turbine has also been improved to work efficiently in low-pressure water sources by installing an internal guide device. The results of the experiment showed that with a water pressure of 2 meters and a water flow rate of 200 l/s, the efficiency of the hydroturbine was 76.3%.

The hydraulic unit [7] consists of a counter-rotor hydraulic turbine and a hydro generator. A counter-rotor turbine has two coaxial impellers (rotor and counter-rotor) rotating in different directions, to which a stream of water is sequentially supplied. In the counter-rotor hydraulic unit, the rotor of the hydro-generator is installed on the same shaft with the rotor of the hydraulic turbine, and the counter-rotor is mounted on the counter-rotor of the hydraulic turbine.

The disadvantage is that at low water pressures, the outflow of water from the upper impeller of the hydraulic turbine occurs in a vortex mode, which leads to large

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energy losses. Also, due to the local resistance of the second guide vane and the impeller, energy is lost. As a result, the efficiency of this system will be low, and at heads of 2-10 m, the complex does not give the desired result.

To calculate the reactive force FA created by the water leaving the impeller nozzle, the change in the momentum of the incoming and outgoing water in it is determined and the force acting on the nozzle at point A is expressed as follows:

$$F=\rho S_3\upsilon_3^2\left(\cos\beta+\sqrt{\frac{S_3}{NS_4}\left(1-\frac{S_3}{S_4}\right)+1-\frac{1}{2}(\xi_{S6}+\xi_2);}\right); \qquad (1)$$

This design power is the power generated by a single nozzle and is determined by multiplying the total reactive power by the number of nozzles. In this case, the absolute speed of the water jet leaving the nozzle is calculated by the following formula:

$$\upsilon_4=\upsilon_3\sqrt{\frac{4S_3}{\pi d_6^2}\left(\frac{4S_3}{\pi d_6^2}-1\right)+1-\frac{1}{2}\left(\frac{0{,}25\lambda}{2}\frac{1}{2}\left(1-\frac{\pi d_6^2}{4S_3}\right)+\left(1-\frac{4S_3}{\pi d_6^2}\right)^2\right)}; \qquad (2)$$

$$\upsilon_3=\frac{\Gamma}{\tau}e^{i(\alpha_2-\beta)}+\upsilon_2 e^{i(\alpha_2-\alpha_1)}. \qquad (3)$$

где $\tau=\frac{\pi d_2}{k}$; $\Gamma=\frac{\pi d\upsilon_2\sin\alpha_1}{\pi d_2}=\frac{l\upsilon_2\sin\alpha_1}{d_2}$;

Here υ3, υ4 are the water velocity at the entrance to the nozzle; υ2 is the water velocity at the exit from the guide vane; S3, d6 are the nozzle inlet surface and nozzle outlet diameter, respectively; α1 and α2 are the angles of water inlet and outlet in the guide vane; l and τ are the length and pitch of the blade, respectively; β is the installation angle of the guide vanes relative to the radial direction.

Using the general theorem on the change in the kinetic moment when a rigid body moves relative to a fixed frame of reference (with the ground), and a moving frame of reference (with the center of the impeller), the torque on the working shaft of the wheel is determined as follows:

$$M_z=-N\pi\rho r_c^3\upsilon_4(\upsilon_4-\omega_z r_c); \qquad (4)$$

Using formulas (1) and (4), we find the cyclic frequency ωz of the impeller:

$$\rho\cdot S_3\cdot\upsilon_3^2\left(\text{Cos}\beta+\frac{\upsilon_4}{\upsilon_3}\right)-N\cdot r_c\rho\cdot S_3\cdot\upsilon_3^2\left(\text{Cos}\beta+\frac{\upsilon_4}{\upsilon_3}\right)=\frac{N}{2}\pi\rho\cdot r_c^3\upsilon_4(\upsilon_4-\omega_z\cdot r_c) \qquad (5)$$

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$$\omega_z = \frac{\upsilon_4}{r_c} - \frac{2S_3\upsilon_3^2\left(\text{Cos}\beta + \frac{\upsilon_4}{\upsilon_3}\right)}{\pi \cdot r_c^3}; \quad (6)$$

The angle formed by the normal to the inner wall of the nozzle with the guide vanes of the jet turbine will be denoted by α1, since the distance to the impeller is very small. After transformations we get:

$$u_3 = \frac{\upsilon_3 \sin(\beta - \alpha_1)}{\sin\beta}; \quad (7)$$

To achieve the lowest possible absolute velocity of the water leaving the impeller, v2=u3 must be. In this case:

$$\sin\beta \cdot (\text{ctg}\alpha_1 - \text{ctg}\beta) = 1 \quad (8)$$

Provided that the width of the water inlet of the diverter blades and the impeller nozzles is the same, then the width of the diverter outlet and inlet nozzles will be υ3sinα1, then:

$$\upsilon_3 \sin\alpha_1 = v_2 \sin\alpha_2 \,)$$

In active turbines, the speed of water entering the impeller corresponds to the full value of the operating pressure; with further movement of water, the speed does not increase, therefore υ3= v2= u3.

After the replacement, the equation becomes:

$$\sin\alpha_2(1+\text{ctg}^2\alpha_1)=2\text{ctg}\alpha_1 \quad (9)$$

Since the parallelogram (for velocities u3 and υ3) forms a triangle with a common base υ3, then we get β = 2α.

The angle α1 usually ranges from 20° to 30°, while for active turbines β should be 40°-60°. With α1=20°, from formula (9) we obtain α2 = 40°. In this case, the absolute output speed will be very large. It follows that the parts of the impeller must be of the same width.

For the active pipe we have:

$$u_{a1}\sin 2\alpha_1 = \upsilon_{a1}\sin(2\alpha_1 - \alpha_1)$$
$$u_{a1} 2\sin\alpha_1 \cos\alpha_1 = \upsilon_{a1}\sin\alpha_1$$
$$2u_{a1}\cos\alpha_1 = \upsilon_{a1} \quad (10)$$

For α1 = 25° we get the following result:

$$ua1=0.55\upsilon a1=0.55\upsilon 4 \quad (11)$$

where υ4 is the speed of the water flow leaving the nozzle, i.e. jet velocity in front of the blade. The power of an active hydraulic turbine is determined by the expression:

$$P = \frac{\rho Q N \upsilon_4^2}{2}, \qquad (12)$$

The efficiency of a jet turbine is 67% -86% depending on the head, and for the speed coefficient at a water flow rate of 15 l / s at a head of 2 meters, the following result was obtained in the experiment:

$$n_s = f\left(\frac{Q}{Q_e}\right)^{\frac{1}{2}}\left(\frac{H_e}{H}\right)^{\frac{3}{4}} = \frac{3{,}65nQ^{\frac{1}{2}}}{H^{\frac{3}{4}}} = \frac{3{,}65 \cdot 723{,}6 \cdot \sqrt{0{,}015}}{2^{\frac{3}{4}}} = 191{,}2 \text{ rpm}$$

Here Q, Qe are the water consumption in the model and in nature, respectively; H and He - water pressure in the model and in nature, respectively.

The following results were obtained during the study:

- When an active impeller is installed on the outgoing high kinetic energy water flow from the jet turbine, the power generation is increased by 25-40% depending on the pressures, in addition to the electricity generated by the jet turbine, according to the water pressure.

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