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STUDY OF CONSTRUCTIVE DIMENSIONS OF KAPLAN HYDRO TURBINE IN VARIABLE WATER FLOWS

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Abstract
Presents the results of research on improving the efficiency of a new type of improved vertical-axis hydropower device for water flows coming out of pump units and used for cooling technological devices in enterprises in changing water flows. The angle of contact of the water flow b 1 entering the hydro turbine blade and b 2 leaving it with the blade, the method of determining the optimal angle of inclination of the blades is presented. Mathematical modeling uses Matlab/Simulink system. The values of the water consumption and the angle of contact of the water flowing into the blades were determined for the case where the water pressure was changed to 1...5 m and the power of the hydro turbine was changed to 5...25 kW. It is based on the possibility of providing uninterrupted electricity to autonomous or enterprises' small power consumers using this hydropower device.

Keywords: Kaplan hydro turbine, water consumption, water flow rate, Matlab/Simulink system, turbine rotation speed, inlet and outlet angles of water flow to blades.

Introduction

In recent years, in the context of the ongoing global energy crisis, special attention has been paid in all countries to the development of more energy resources and efficient use of energy. This causes the development of state programs and scientific and practical work on their implementation in order to increase the production of electricity. In such a situation, the main solution to the above problems is paying great attention to the establishment and improvement of the efficiency of power plants operating on renewable energy sources, in particular, solar, wind and hydropower plants. Currently, the low energy efficiency of solar and wind power plants in the world and the fact that most of the energy resources are used for the construction of large-capacity hydroelectric power plants (HPP) limit the construction of such facilities. In this case, it is necessary to develop small hydroelectric power stations and increase their efficiency [1].

A number of measures to reform the hydropower sector are being implemented in Uzbekistan. Between 2023 and 2030, it is planned to increase the total capacity of hydropower in the republic to 4999 MW. In particular, with the participation of JSC "Uzbekgidroenergo" and private investors, an additional 748.9 million kW will be created by 2030 through the construction of small and micro hydroelectric power plants with a project cost of 328.8 billion US dollars and a total capacity of 143.6 MW in Surkhandarya, Fergana, Kashkadarya and Tashkent regions. It is planned to produce electricity per hour [2].

Despite the fact that a number of scientific and technical studies are being carried out on the creation and improvement of the efficiency of micro hydropower devices operating in variable water currents, in the southwestern regions of our country , modeling of vertical axis hydropower devices adapted to variable water flows and determining their optimal angle of inclination in reducing the forces of water wheel blades acting on the water flow and Scientific studies on increasing the efficiency of the device have not been carried out enough.

Scientific research on the development of micro hydropower devices is being carried out by experts in the field. A hydropower device that operates on variable water flows is known, and its principle of operation is as follows: fixed guide vanes placed in the body of the device transmit the water flow to two propeller-type hydroturbines that are able to rotate under the influence of the water flow attached to one fixed shaft . In turn, mechanical energy is transmitted to the rotor of the electric generator through mechanical transmissions installed on the outside of the rotating water wheel at the top of the device . Due to the use of fixed guide vanes and two water wheels in the device , the efficiency of operation has been significantly increased. Disadvantages of this device are complex construction, low reliability and use of many materials [3] .

A hydropower device for vertical water flows is known, which consists of a diverting device, a Savonius type hydro turbine and an electric generator . The rotating water wheel of this known hydropower device is directly connected to the rotor of the generator. Disadvantages of this hydropower device are the high resistance forces of the water wheel blades in contact with water and the low efficiency of operation in low-pressure water flows [4] .

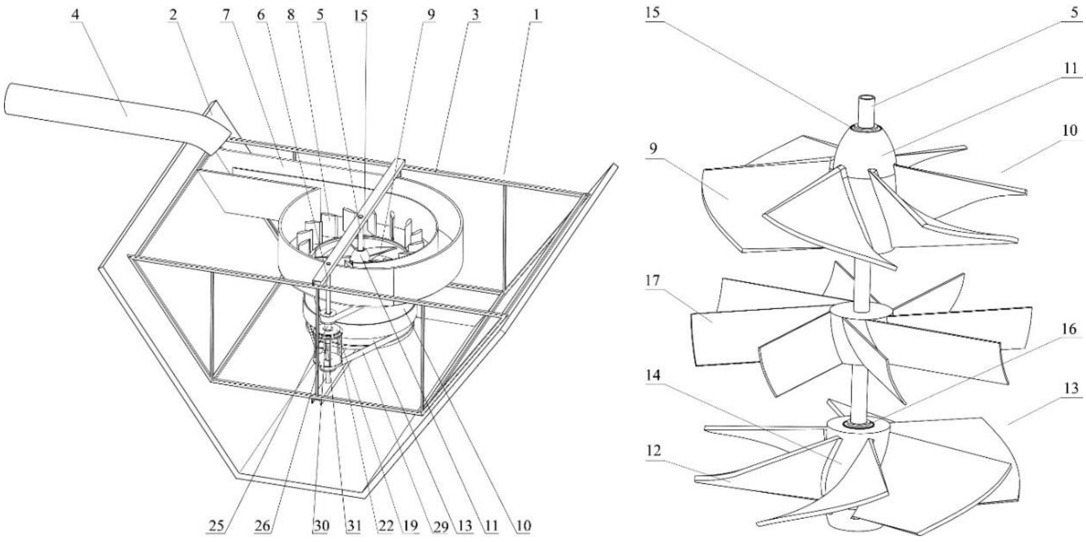
A vertically installed hydropower device is known for obtaining electricity using low-pressure currents in water pipes, and the principle of operation of this device is as follows: in the device, fixed devices attached to the pipe through bearings are attached to a shaft whose blades are equipped with a propeller-type water wheel, and this shaft is mechanically connected by chain gears. transmits energy to the rotor of the electric generator . Disadvantages of the hydropower plant: the lack of a device that directs the flow of water in the pipe to the blades, the low-pressure water flow efficiency and the low reliability of the electricity produced by the electric generator when the water flow consumption changes. [5] .

The purpose of the study is to increase the efficiency of propeller-type hydro turbine blades in changing water flows by determining the optimal angle of inclination.

a) b)

Figure 1. Variable water flow sources (a) "Bukhara Livestock Luck" pump unit on the farm, b) used for cooling technological devices at the Qorovulbazar oil refinery in the Bukhara region pump unit)

The proposed hydropower device works in the following order: a frame 3 consisting of metal profiles is fixed on the water currents of the channel 2, and the water flow is transmitted through the pipe 4 to the vertical axis hydropower device 1 installed on the frame 3 through a fixed shaft 5. Water flow directing apparatus 8 is installed in the special basin 7 where the water flow is rotating, and as a result of the uniform transfer of water flow to the first water wheel 10, the water wheel 10 begins to rotate in a clockwise direction, the first water wheel 10 is below and the second water wheel is On 13 and on the fixed shaft 5, a fixed device 17 that directs the water flow evenly is installed, and as a result of the water flow being transmitted to the second water wheel 13 evenly, the second water wheel 13 starts to rotate in a stable counter-clockwise direction. The first water wheel 10 is connected to the armature 22 of the magnetoelectric axial electric generator 24, which is attached through metal discs 26 and bushings 27, and the second water wheel 13 is connected to the inductors 19, 20 of the magnetoelectric axial electric generator 24, which is attached to the magnetoelectric axial electric generator 24 through the flange joint 25, through belt drives 28, 29. the action is transmitted. Three-phase alternating electric energy is obtained from brushes 30 and collectors 31 from the magnetoelectric axial electric generator 24, which consists of the armature 22 of copper coils 23, inductors 19, 20 and permanent magnets 21 installed on the fixed shaft 6 . In this case, the armature 22 and the inductor 19, 20 of the magnetoelectric axial electric generator 24 are counter-rotated relative to each other, and high electromagnetic power is obtained at low rotational speeds. The developed device was granted an invention patent by the Intellectual Property Center under the Ministry of Justice of the Republic of Uzbekistan (IAP 20230169). Figure 2 shows the hydropower plant general view (a) (b) is an axonometric projection of the water wheel blades and the fixed device that directs the water flow evenly.



a) b)

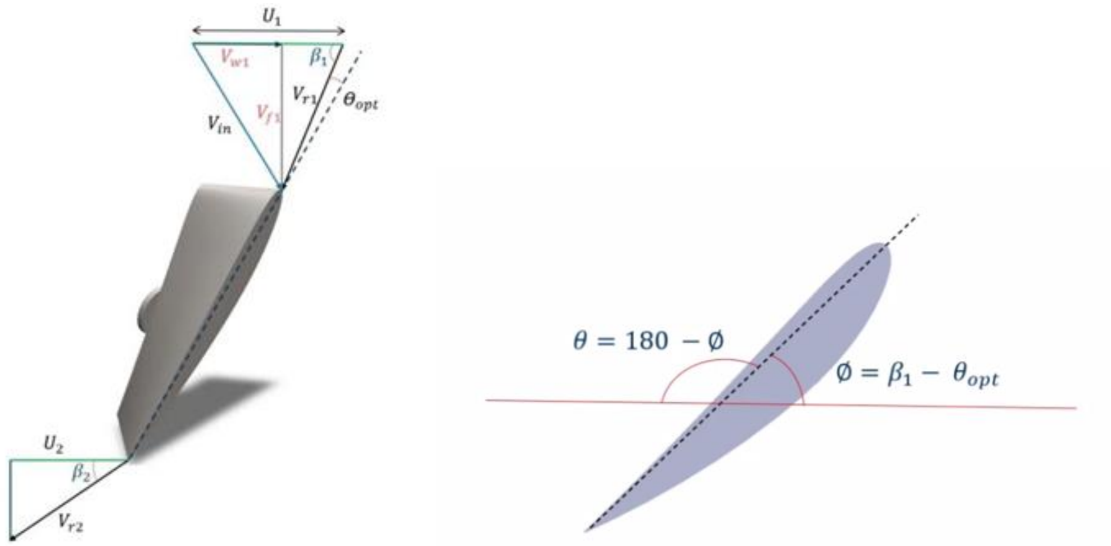
Figure 2. General view of the hydropower plant (a) axonometric projection of the water wheel blades and the fixed device that directs the water flow evenly (b)

The output power of the water flow is determined by the following mathematical expression [6,7] :

$$P = \eta \cdot \rho \cdot g \cdot Q \cdot H (1)$$

where: η – useful turbine efficiency; ρ ─ density of water, kg/m ^{3} ; g ─ эrkin descent acceleration, m/s ^{2} ; Q ─consumption of water flow, m ^{3} /s; H ─ water napori, m.

Figure 3 shows the velocity diagram (a) and the vertical shear (b) of the blade. In this case, the optimal installation angle of the blades depends on the change in the pressure of the water flow.



a) b)

Figure 3. Velocity diagram of the blade (a), vertical shear of the blade (b)

Turbine quoted speed [8] :

$$N_S = \frac{885{,}5}{H^{0,25}} = \frac{N\sqrt{P}}{H^{5/4}} \qquad (2)$$

where: N – turbine rotation speed, rev/min.

(2) of the turbine from the expression we determine the rotation speed [9] :

$$N = \frac{N_S \cdot H^{5/4}}{\sqrt{P}} \qquad (3)$$

Diameter of water wheels [10]

$$D_{run} = \frac{84{,}5 \cdot \emptyset \cdot \sqrt{H}}{N} \qquad (4)$$

where: $\emptyset = 0{,}0242\ N_S^{2/3}$–the angle of inclination of the parrack.

Bushing diameter

$$d_{hub} = m \cdot D_{run} \qquad (5)$$

where: m –is the relationship between the diameters and is determined depending on the pressure of the water flow.

Consumption of water flow

$$Q = \frac{\pi}{4}(D_{run}^2 - d_{hub}^2) \cdot V_{f1} \quad (6)$$

where: V_{f1} – speed of water flow, m/s.

(6) of water flow from the expression we determine the speed:

$$V_{f1} = \frac{Q}{S} = \frac{Q}{\frac{\pi}{4}(D_{run}^2 - d_{hub}^2)} \, (7)$$

where: S – the surface of the water flow, m ^{2}.

Circulation speed of water flow [11]

$$V_{w1} = \frac{P}{\rho \cdot Q \cdot U_{avg}} \qquad (8)$$

Tangential speed of hydro turbine blades

$$U_{avg} = \frac{\pi \cdot D_{avg} \cdot N}{60} \qquad (9)$$

where: D_{avg} – the diameter of the bar, m.

Angle of water flow to the blades [12]

$$\beta_1 = arc\ tg \frac{V_{f1}}{U_1 - V_{w1}} \qquad (10)$$

The angle of exit of the water flow from the blades

$$\beta_2 = arc\ tg \frac{V_{f2}}{U_2} = arc\ tg \frac{V_{f1}}{U_1} (11)$$

The distance between the wings

$$t^{'} = \frac{\pi \cdot D_i}{Z} \qquad (12)$$

where: Z – is the number of blades in the water wheel, which is determined based on the relationship between the pressure of the water flow and the diameters.

The length of the outer part of the hair

$$c_{out} = 0{,}75 \cdot t^{'} \qquad (13)$$

The length of the inner part of the hair

$$c_{in} = 1{,}3 \cdot t^{'} \qquad (14)$$

The optimal angle of inclination of the blade

$$\theta_{opt} = \beta_1 - \emptyset \qquad (15)$$

Figure 4 shows the dependence curves of water flow pressure change on water consumption (a) and the angle of water flow to the blades (b). In this case, calculations were made for the output power of the water flow of 5...25 kW, respectively. So we can see that when the water pressure changes, the exit angle of the water flow from the filter changes.

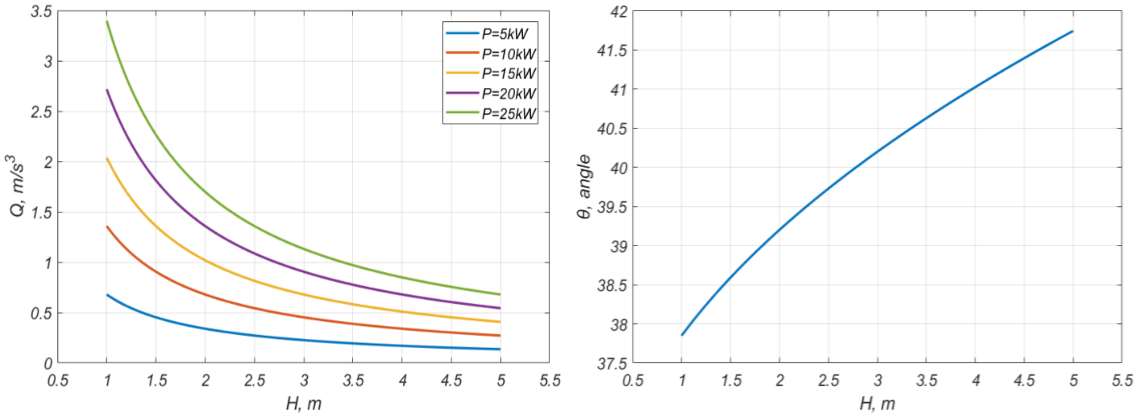


Figure 4. Curves of the dependence of the change in water flow pressure on water consumption (a) and the angle of water flow to the blades (b)

Conclusion:

Studies on improving the efficiency of the improved vertical axis hydropower device for water flows coming out of pumping units and used for cooling technological devices in enterprises in variable water consumption and pressure were analyzed. The method of determining the contact angles of the water flow b $_{1}$ and b $_{2}$ leaving the blades of the hydro turbine with the blade, the optimal angle of inclination of the blades θ was developed. For the case where the water pressure is 1...5 m and the power of the hydro turbine is changed to 5...25 kW, the water consumption is 0.6...3.45 m/s ^{3} and the values of the contact angles of the water flow entering the blades with the blades are 38 ^{0} ...42 ^{0} . It was found that using this hydropower device, it is possible to provide uninterrupted electricity to small-capacity consumers of the autonomous or enterprise.

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