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Increasing Energy Efficiency of the Executive Mechanisms of Intellectual Systems

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Increasing Energy Efficiency of the Executive Mechanisms of Intellectual Systems

A Djalilov [α], R Baratov [σ], E Sobirov [ρ], M Begmatov [Ѡ] & X Valixonova [¥]

Abstract- At the same time, the demand for water and energy resources around the world is growing year by year.This requires the efficient use of available water and energy resources.Currently, attention is paid to the low energy consumption of devices manufactured in all areas.In particular, in our country, scientific research is being conducted to create energy-efficient devices in the water management system.This article is devoted to the positive solution of the listed problematic issues.

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I. Introduction

To ensure a stable and guaranteed water supply for all segments of the population and the economy, our country is carrying out large-scale work to develop irrigation, improve water infrastructure and reclamation of irrigated lands, efficient and rational use of land and water resources.

However, due to global climate change, population growth and increasing demand for water from year to year, the growing shortage of water resources may be one of the main limiting factors for the future development of the country.

Insufficient introduction of modern water and energy saving methods and technologies in the water sector, that is, open irrigation networks, the introduction of scientific achievements and know-how, as well as the widespread use of modern information and communication technologies and innovative solutions hinder the development of the industry.

Consequently, the effective management of water resources and rational use of water in the country, the reform of water management and the widespread introduction of market principles and mechanisms, information and communication technologies and energy efficient technologies, as well as the effective use of scientific potential in the field of water and food security.

II. Method

In Uzbekistan, flat and rectangular vertical opening slide gate are widely used in water distribution networks. To determine the value of the hydrostatic pressure force on a straight rectangular flat surface, the following studies are necessary. Determination of the pressure force is one of the important parameters when choosing the design of a hydraulic gate or other hydraulic systems.

Figure 1 below shows a schematic of a flat vertical moving slide gate. It is known from the course of fluid mechanics that the force of hydrostatic pressure acts perpendicular to a flat surface. Usually the force exerted by the hydrostatic pressure is located at the center of gravity of the flat body (see the point in Figure 1) [1,2].

Consider a completely closed state of the gates, in which case the upstream head (water level) in the head water will have a maximum value.The $S = H_{up.max} \cdot b$, m^2 formula is used to determine the total surface area of a hydraulic gate under hydrostatic pressure, where $H_{up.max}$ –upstream head (water level) or height of the gate (m), b – width of the gate (m). As we know, the expression for the effect of hydrostatic pressure is as follows [2,4,5].

$$F_R = \rho \cdot g \cdot \frac{H}{2} \cdot S = \rho \cdot g \cdot \frac{H}{2} \cdot H \cdot b = \frac{1}{2} \rho \cdot g \cdot H^2 \cdot b \quad (1)$$

This expression can be used in practice for any case of hydraulic gates. However, to determine the coordinate dependence of the forces acting on the flat surface of hydraulic gates, we analyze gates with a flat surface moving vertically.

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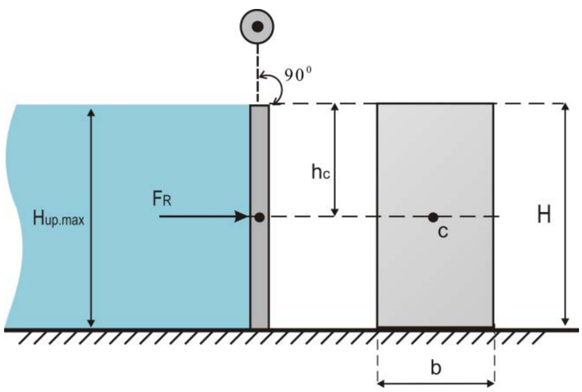

Figure 1: A rectangular vertical moving hydraulic gate

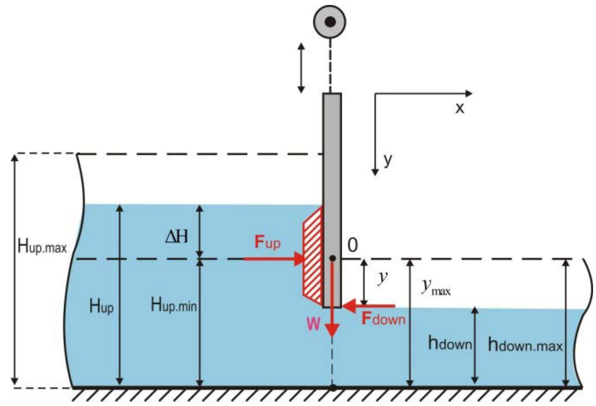

Figure 2: Forces of hydrostatic pressure affecting a vertically moving hydraulic gate

Figure 2 shows the hydrostatic pressure forces affecting on a vertically moving hydraulic gate. The resulting hydrostatic pressure force is equal to the following [4,5]:

$$F_R = F_{up} - F_{down}\,, \qquad (2)$$

where $F_{up,}$ F_{down}- are the forces affecting the hydrostatic pressure in the upstream and downstream, respectively.

The hydrostatic pressure force Fdown at the bottom is very small and can be ignored, therefore:

$$F_R = F_{up} \qquad (3)$$

An important parameter in determining the total forces affecting the flat surface of the hydraulic gate is the water level in the upstream and downstream of the canal.Taking into account the laws of water level change in the upstream and downstream, we determine the total force of hydrostatic pressure affecting the hydraulic gate as follows [4,5,6]:

$$F_{overal} = k(f \cdot F_R \pm W) = k[\frac{1}{2} \cdot f \cdot \rho \cdot g \cdot b \cdot (H_{up.min} + \Delta H \cdot y - h_{down.max}(y_{max} - y))^2 \pm W] \qquad (4)$$

where k - reserve coefficient, W - weight of the gate (N), f - friction coefficient (dimensionless coefficient), H_{up}, $H_{up.min}$ –water level in the upstream and its minimum value, ΔH – difference between the water level in the upstream and its minimum value, h_{down},$h_{down.max}$ – downstream water level and its maximum value, y, y_{max} – coordinate of the hydraulic gate and its maximum value.

In equation (4) weight ofthe gate (W) has negative and he positive sign means that weight of the gate at the closing process has the same direction with closing force helping to close the gate and at the opening process directed opposite to the opening force.A positive value means that the movement of the gate follows the direction of the gate weight vector. A negative value means that the direction of movement of the gate and the vector of the weight of the gate are in the opposite movement.

In figure 3 shows the curve of changes in hydrostatic pressure affecting the flat surface of the gate due to the movement of the coordinate of the hydraulic gate.

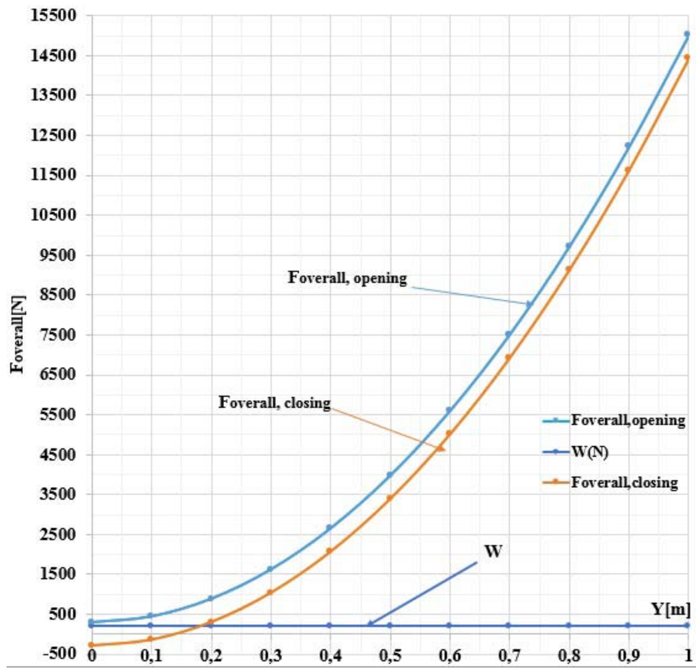

Figure 3: Coordinate dependence of the hydrostatic pressure force affecting on a flat surface when opening and closing a vertically moving gate

It is known from the graph that the influence of hydrostatic pressure is less when closing the valve than when opening it.There is a big difference between these impact forces and it will be the basis for us to analyze water level and flow control and energy-saving designs of control systems.From the point of view of the design of the hydraulic gate under analysis, it can be observed that in the preparation, installation and operation of the hydraulic gate there are some shortcomings in the management system of such a gate:

- An increase in the weight of the gates requires an increase in the electric motor power of the gates accordingly;
- Corrosion of mechanisms, gearing of drive mechanisms and other additional loads lead to an increase in energy consumption accordingly.

The power consumption of a vertically moving hydraulic gate is determined as follows:

$$P = \frac{F_{overal} \cdot v}{\eta} \quad (5)$$

where F_{overal} - total force affecting the gate, η- total F.I.K. lifting mechanism, v - lifting speed.

The second type - the determination of the water flow rate in hydraulic gates moving at a certain angle, depends on the angle of rotation of the gates and the water level (Figure 4) [3,4].

Currently, this method of monitoring and measuring water flow in open canals is most widespread due due to the following advantages: small amplitude of oscillations of the surface wave of water when adjusting the flow rate, simplicity of design, as well as the ability to perform a large range of measurements when measuring, adjusting the level and flow of water - one of the benefits.

The rotating part of the hydraulic gate, which moves at a certain angle, is attached to the lower part of the channel, and the upper part is connected to the drive mechanism by means of two cable wires. As the angle of rotation of the flat basin changes, the water level in the upstream and doenstream changes accordingly.

A number of theoretical and experimental studies have been conducted to determine the energy savings of this construction and a mathematical model of it has been developed accordingly.

$$S_{down} = b \cdot h_{down} \text{ or } S_{down} = b \cdot h_{down} = b \cdot h_{down.max} \cdot \sin(\alpha_{max} - \alpha) = b \cdot h_{down.max} \cdot \cos\alpha \quad (6)$$

where α, α_{max} –then angle of rotation of the gate and its maximum value, $\alpha_{max} = 90^0$.
From the construction shown in Figure 4, the following can be written:

$$H_{up} = L + L', \text{ where } L' = H \cdot \sin\alpha, \text{ or } L = H_{up} - L' = H_{up} - H \cdot \sin\alpha. \quad (7)$$

The level from the water surface in the headwater to the center of the partition is as follows:

$$h_c = L + \frac{1}{2}L' = H_{up} - H \cdot \sin\alpha + \frac{1}{2} \cdot H \cdot \sin\alpha . \quad (8)$$

Using expressions (7) and (8), we get:

$$h_c = H_{up.min} + \Delta H \cdot \sin\alpha - H \cdot \sin\alpha + \frac{1}{2} \cdot H \cdot \sin\alpha = H_{up.min} + \left(\Delta H - \frac{1}{2}H\right) \cdot \sin\alpha \quad (9)$$

Multiplying the level h_c from the water surface to the center of the hydraulic gate of water on the surface of the headwater (S_{up}), we determine the force of hydrostatic pressure affecting on the upper surface of the hydraulic gate as follows [4,5]:

$$F_{up} = \rho \cdot g \cdot h_c \cdot S_{up} = \rho \cdot g \cdot \left(H_{up.min} + (\Delta H - \frac{1}{2}H) \cdot \sin\alpha\right) \cdot b \cdot H =$$

$$= \rho \cdot g \cdot w \cdot \left[H_{up.min} + (\Delta H - \frac{1}{2}H) \cdot \sin\alpha\right] \cdot H . \quad (10)$$

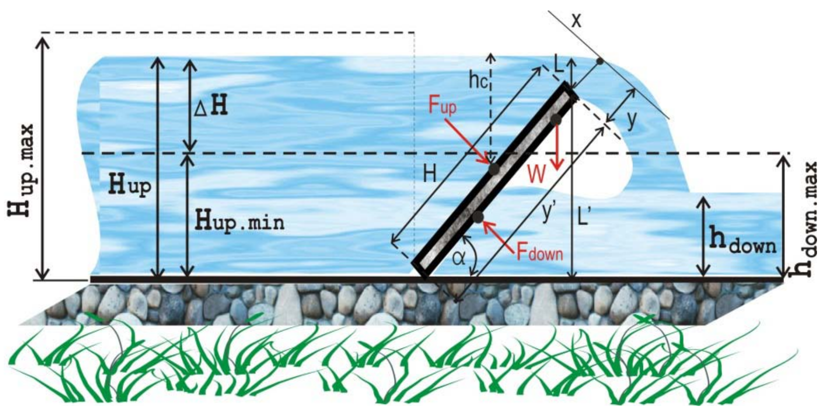

Figure 4: Straight rectangular valve moving at a specific angle

This design has a hydrostatic pressure force that also affects the downstream and must be taken into account. Because in some cases the water level in the downstream is a much larger value and the hydrostatic pressure force depends on the value of this water level. Therefore, the water level in the downstream to the center of the immersed surface is as follows:

$$h_c = \frac{1}{2}h_{down} = \frac{1}{2}h_{down.max} \cdot \sin(\alpha_{max} - \alpha) = \frac{1}{2}h_{down.max} \cdot \cos\alpha \quad (11)$$

In this case, the hydrostatic pressure force generated by the downstream is as follows [4,5]:

$$F_{down} = \rho \cdot g \cdot h_c \cdot S_{down} = \frac{1}{2}\rho \cdot g \cdot h_{down.max} \cdot \cos\alpha \cdot b \cdot h_{down.max} \cdot \cos\alpha =$$

$$= \frac{1}{2}\rho \cdot g \cdot w \cdot [h_{down..max} \cdot \cos\alpha]^2 = \frac{1}{2}\rho \cdot g \cdot b \cdot h_{down}^2 . \quad (12)$$

Compared to a vertical hydraulic gate, several forces act on this type of hydraulic gate during opening. In particular, these are: the weight of the hydraulic gate, friction resistance, that is, the resistance caused by the hydrostatic force acting on both sides of the gate.

Thus, the sum of the forces affecting on the horizontal hydraulic gate is:

$$F_{overal} = \pm F_{up} \mp F_{down} \pm W . \quad (13)$$

The resulting force, known from expression (13), has positive and negative components, and these expressions depend on the direction in which the gate moves up or down. For example, a negative sign means that the hydraulic gate moves in the same direction with the force that drives it during opening or closing.

(4) The values of the total force acting on the horizontal hydraulic gate during its opening or closing are as follows:

When lifting (closing) the gate

$$F_{overall\,closing} = k(f \cdot F'_{over.closing} \pm W) = k \cdot \left[f \cdot \rho \cdot g \cdot b \cdot ((H_{up.min} + (\Delta H - \frac{H}{2}) \cdot \sin\alpha\ ) \cdot H - \frac{1}{2}(h_{up.max} \cdot \cos\alpha\ )^2) + W \cdot \cos\alpha \right] \quad (14)$$

When lowering (opening) the gate

$$F_{overall\,opening} = k \cdot \left[-f \cdot \rho \cdot g \cdot b \cdot ((H_{up.min} + (\Delta H - \frac{H}{2}) \cdot \sin\alpha\ ) \cdot H - \frac{1}{2}(h_{down.max} \cdot \cos\alpha\ )^2) - W \cdot \cos\alpha \right] \quad (15)$$

Thus, we construct a graph of the coordinate dependence of the hydrostatic pressure forces affecting on the gate during lifting and lowering (Fig. 5).

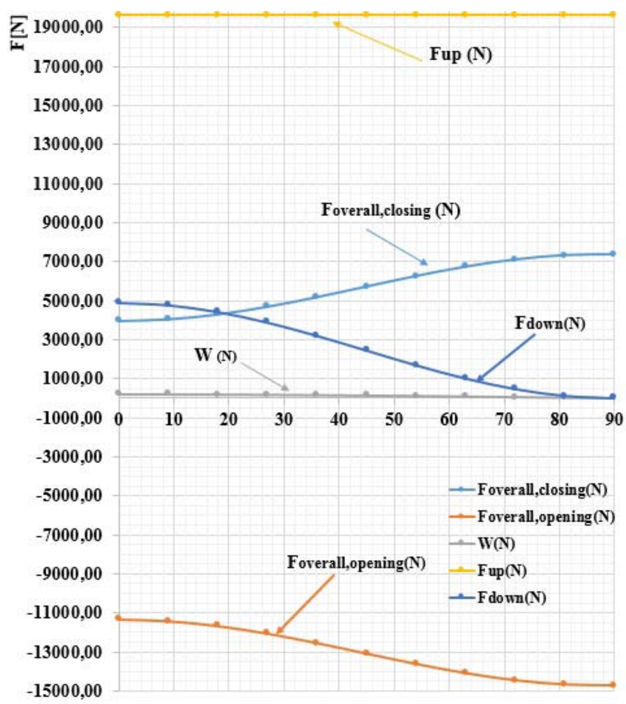

Figure 5: Forces of hydrostatic pressure acting on a hydraulic gate moving at a certain angle

III. Results and Discussions

Analysis of this process showed that the hydrostatic pressure force (F_{up}) in the headwater can be constant or variable depending on the channel parameter.But the change interval is not very large. The difference in the hydrostatic pressure forces affecting on the hydraulic gates during opening and closing is approximately 18760 N.This value is 32 times less than the force affecting on the vertically moving gate.Optimization of several process parameters of the system control and monitoring improves the energy efficiency of hydraulic gates.

Nowadays, most hydraulic gates have an automatic control and monitoring system.

During irrigation, a large amount of electricity is required to control and monitor the condition of the hydraulic gates. In addition, many hydraulic gates or water distribution points are located far from power lines, which creates additional difficulties in the operation of open canals. The above problems require the development of energy-saving systems for the control and monitoring of the state of hydraulic gates.

- Typically, the following two elements of hydraulic gates are the main energy consumers:
- Screw or chain gate lifting mechanism;
- Reducers to control the speed of movement of hydraulic gates.

Electric motors are the main gate control mechanism. Several parameters increase power consumption. For example, high-speed gates consume a lot of electricity.

The power of the electric motor for lifting and opening the gate is determined by the following expression:

$$P = \frac{F_{\text{overall closing}} \cdot v}{\eta}, \quad (16)$$

$$P = \frac{F_{\text{overall opening}} \cdot v}{\eta}, \quad (17)$$

where $F_{overall\ closing}$,$F_{overal\ opening}$- opening is the total force affecting the gate, η- the total F.I.K. lifting mechanism, v - lifting speed. Typically, the lifting speed is$v$=0,25–0,3 m/min, and the overall F.I.K of the hoist depends on which mechanism is used. For example, if a screw mechanism is used for lifting, its F.I.K is η=0,63-0,85.

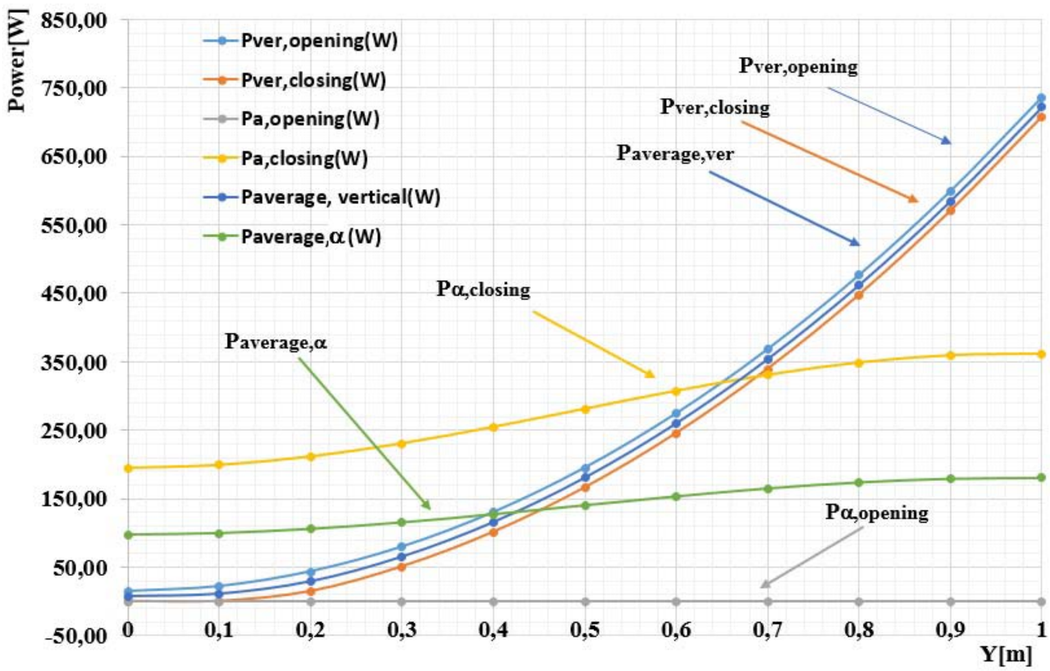

Figure 6: Power consumption of electric motors at a certain angle and vertically moving gates

IV. Conclusions

Analyzing the energy consumption for the coordinate movement of the gates from Figure 6, we can conclude the following:

- The average power required under the same conditions is 236.69 W for vertically moving gates and 139.88 W for hydraulic gates moving at a certain angle. Based on this energy consumption, if we compare the vertical and certain angles under the same conditions, then hydraulic valves moving at a certain angle consume 1.8-2 times less energy than vertical ones;
- Intellectual control and measurement system optimization of several parameters of the working process improves the energy efficiency of hydraulic gates;
- Reducing the energy consumption of the intellectual system execution mechanism allows to increase the efficiency of the system.

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