Simulation of the Lift of Two Sequential Gate Valves of the Karkidon Reservoir

***Khudaykulov Savet Ishankulovich*[1], *Usmonova Nodirakhon Akramovna*[2], *O'tbosarov Shuhratjon Rustamjon ugli*[2]**

[1]*Doctor of Technical Sciences, Professor, Scientific Research Institute of Irrigation and Water Problems, Tashkent, Korasuv*

[2]*Assistant, Fergana, Ferghana Polytechnic Institute, Ferghana, Uzbekistan*

ABSTRACT

The article describes a method for constructing a lifting schedule for the gates of the Karkidon reservoir, which provides a satisfactory hydraulic regime behind the gates and reduces the requirements for the accuracy of the operation of their drive mechanisms.

KEYWORDS: *Aeration shaft, gate, gate resistance coefficients, hydraulic conditions, isobar.*

Introduction

The purpose of the work is to choose such a mode of lifting the gates of the Karkidon reservoir, which would provide satisfactory conditions behind the gates, and the requirements for the accuracy of its implementation would be the smallest. Establishing the conditions for the deviation of the gate travel from the selected mode and the optimal redistribution of the pressure between them.

Behind the gates of the water supply galleries of the Karkidon reservoir, there is a rapid current, which is the cause of strong erosion and destruction. Therefore, finding satisfactory hydraulic conditions is one of the urgent tasks and preservation methods. One of the ways to ensure satisfactory hydraulic conditions behind the gates of water supply galleries is to use two sequentially installed gates (Fig. 1).

In this case, the lower gate II will create additional resistance, gradually decreasing as it opens. The head is divided between both gates, and the hydraulic regime behind each of them is improved compared to the regime with one gate with the same head.

Fig. 1. Dam of the Karkidon reservoir

A number of theoretical and experimental works [1, 2, 3] showed the effectiveness of this method, but its main disadvantages were also revealed: an increase in the length of the gate section, since the gates should be located at a considerable distance from each other; high requirements for the control system of the gate operation, since when the gate travel deviates from the selected mode, the pressure is redistributed between them, and the hydraulic conditions behind one of them deteriorate sharply.

The pressure behind the first gate can be determined by the formula [1]:

$$\frac{p_1}{\gamma} = h_t + \left(\varsigma_2 - 1 - 2\sqrt{\varsigma_{зт_1}} + \varsigma_{зт_2}\right) \qquad (1)$$

after the second - according to the formula:

$$\frac{p_2}{\gamma} = h_t + \left(\varsigma_2 - 1 - 2\sqrt{\varsigma_{зт_1}}\right)\mu_t^2 H_t \qquad (2)$$

The head at each moment of time is determined by the equation [1,3]:

$$\sqrt{H_t} = \sqrt{H_0} - \frac{\omega\sqrt{2g}}{2\Omega}\int_0^t \mu_t dt \qquad (3)$$

$$\mu_t = \frac{1}{\sqrt{\sum \varsigma}} = \frac{1}{\sqrt{\varsigma_1 + \varsigma_2 + \varsigma_{зт_1} + \varsigma_{зт_2}}} \qquad (4)$$

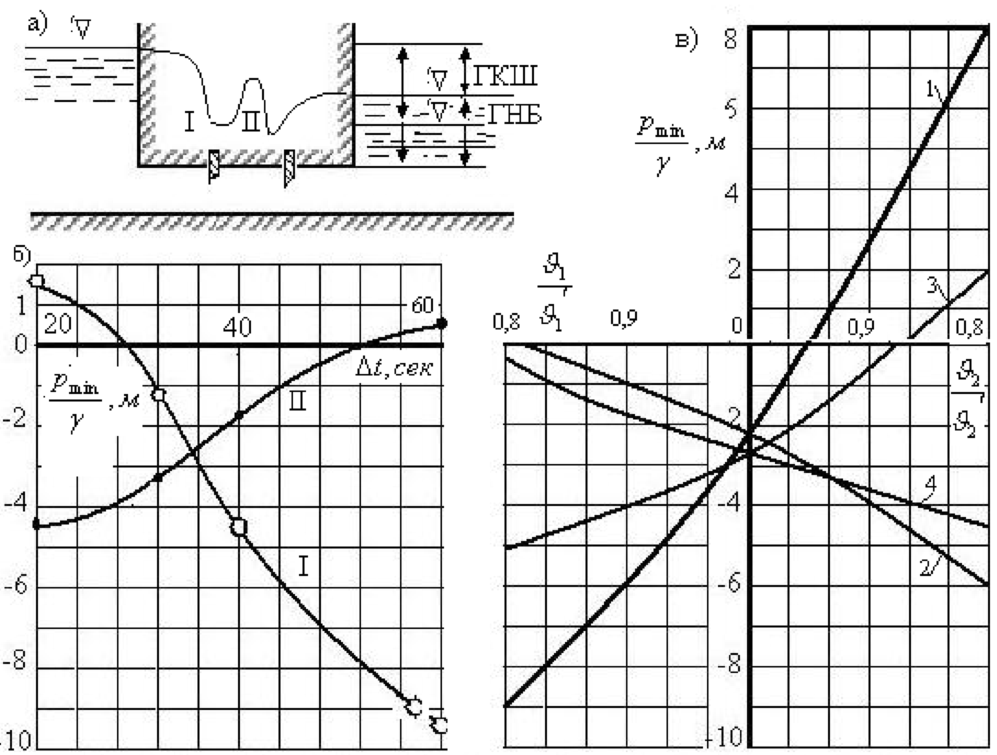

Fig. 2. The influence of the accuracy of the valves on the pressure behind them. A – design diagram of the water conduit; b – the effect of advancing the second gate; c – the effect of changing the speed of one of the gates I and II – gates. ϑ_1, ϑ_2 – assumed lift speeds; $\vartheta_1', \vartheta_2'$ - actual lifting speeds of the gates (taking into account the lagging). 1, 2 – pressure behind the first and second gates at the initial

selection of their lifting mode; 3, 4 – the same with a refined mode.

In these formulas p_1 и p_2 — averaged excess pressure on the gallery ceiling in compressed sections behind the first and second gates (Fig. 2); H_0, H_t - initial head on the sluice and head at time t; h_0, h_t - deepening of the gallery ceiling under the water level in the chamber at the initial moment and at the moment t; Ω - area of the water mirror in the lock chamber; ω - the area of the calculated section of the gallery; ς_1, ς_2 - total resistance coefficients of the gallery sections lying above the first and below the second gates; $\varsigma_{зm_1}, \varsigma_{зm_2}$ - gate resistance coefficients; μ_t - the coefficient of consumption of the water supply system.

From the structure of formulas (1) and (2) it can be seen that if both gates rise synchronously, that is, at each moment $\varsigma_{зm_1} = \varsigma_{зm_2}$, then the pressure behind them will be different; downstream of the second valve, the pressure will be lower and it will work in more severe conditions. To equalize the pressure, the second valve must rise with some advance. Δt. The best solution would be when the minimum pressures behind both $\frac{p_{1мин}}{\gamma}$ and $\frac{p_{2мин}}{\gamma}$ valves are equal.

RESULTS AND DISCUSSION

In the first approximation, the quantity Δt can be determined. However, it is impossible to maintain a given shutter lift schedule with perfect accuracy. Deviations from it can lead to a sharp deterioration in the working conditions of one of them. To assess the influence of the accuracy of the gates operation on the pressure behind them according to formulas (1) – (4), a hydraulic calculation of the gate was made with the following initial data: $H_0 = 60м;\ \Omega = 2160м^2;\ \omega = 16м^2;\ h = 4м;$ $\varsigma_1 = 1{,}5;\ \varsigma_2 = 2{,}0;$ time of uniform lifting of gates $t_{0_1} = t_{0_2} = 200сек;$ Δt changed from 20 to 60 sec. In fig. the values of the minimum pressures during the filling of the gate below the gates are given with different advance Δt. At $\Delta t = 36сек,\ \frac{p_{1мин}}{\gamma} = \frac{p_{2мин}}{\gamma} = -2{,}6 м.вод.ст.$

The same figure shows that if Δt б If it takes 5 seconds longer, then the vacuum behind the first shutter will double.

With a decrease in the lifting rate of one of the gates by 10%, the vacuum behind it increased by a factor of 2–3 (Fig. 1c; curves 1 and 2).

Table 1

n_2	ς_2	ς_1	n_1	n_2	ς_2	ς_1	n_1
0,1	193	12100	-	0,6	2,33	7,3	0,43
0,2	44.7	850	-	0,7	1,1	2,56	0,58
0,3	18,05	175	0,12	0,8	0,64	1,2	0,69
0,4	8,37	50	0,19	0,9	0,34	0,56	0,82
0,5	4,27	17,6	0,31	1,0	0,25	0,36	0,89

It is necessary to find such a lifting schedule of the gates, deviations from which would be the least dangerous. In what follows, we will call such a schedule optimal.

In most cases, the optimal schedule can be built based on the condition that the pressures behind both gates during the period of their rise should be equal, i.e. $p_1 = p_2$ Then, equating the right-hand sides of formulas (1) and (2) making reductions, we get:

$$2\sqrt{\varsigma_{\text{з}m_1}} = \varsigma_{\text{з}m_2} + 2\sqrt{\varsigma_{\text{з}m_2}} \qquad (5)$$

This is the condition for equality of pressures behind both gates. Setting the value of the relative opening of one of the gates (for example, the second $-n_2$ can calculate the required value n_1. The table shows the calculation results for a flat shutter, but in the same way it is possible to determine the dependence $n_1 = f(n_2)$ for other types of closures.

Using this data, the hydraulic characteristic of the sluice can be plotted. It should be noted that if the gates are at different elevations or the space between them communicates with the atmosphere (using an aeration shaft or a surge tank), then dependence (5) is not true. [3,4]

To determine the value of the permissible deviation of the gate travel from the selected schedule $n_1 = f(n_2)$ and, therefore, to assess the requirements for the accuracy of the drive mechanisms, the following construction is proposed.

The hydraulic characteristics of filling (or emptying) the sluice are calculated, according to which it is possible to find the pressure value behind both gates, corresponding to a certain combination of their relative openings n_1 and n_2.

This calculation is done for several values Δt or for different gate lift speeds.

These data are used to construct the pressure fields behind the gates, depending on the ratio n_1 and n_2 (fig. 3), each pair of values n_1 and n_2 there corresponds a point with a certain pressure value behind the first (Fig. 2, a) and the second (Fig. 2, b) gates taken from the hydraulic characteristics. Isobars are drawn along these points $\frac{p_1}{\gamma} = const$ and $\frac{p_2}{\gamma} = const$.

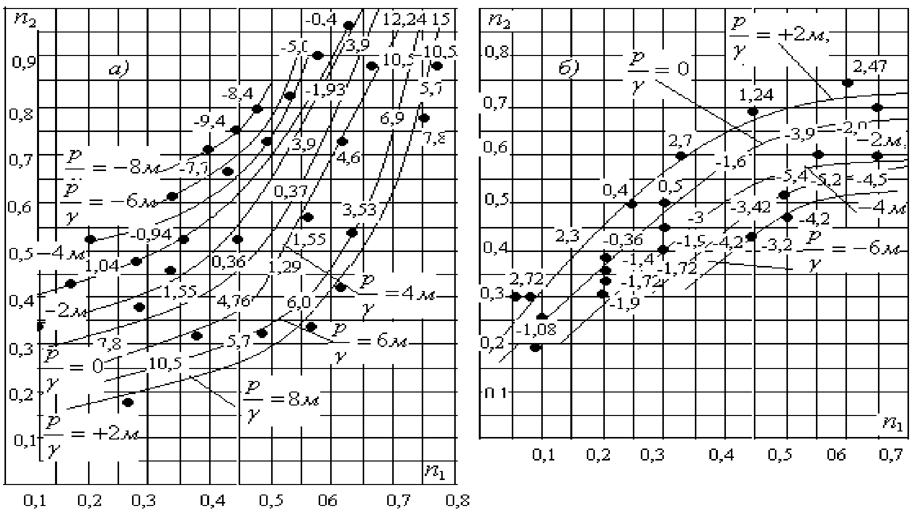

Fig. 3. Pressure $\frac{p}{\gamma}$ m water column behind the shutters with their different openings.

a) - behind the first gate; b) - behind the second shutter

Then both systems of isobars are combined into one nomogram (Fig. 3). With its help, it is possible to determine the pressure behind the gates at any values n_1 and n_2. It should be noted that if the gate lift rates for different calculation options differ very strongly (several times), then one combination n_1 and n_2 in different cases, slightly different values of pressures behind the gates will correspond, because the values of the water levels in the chamber will differ, but this difference is small in comparison with the absolute values of pressures and levels.

From consideration of the nomogram (Fig. 3), we can conclude that for a given gateway with certain parameters there is an area of such corresponding values n_1 and n_2 (in Fig. 3 it is shaded) that if the graph of the connection between them lies in this area, then the vacuum behind the gates will not exceed the permissible value.

The graph corresponding to the previously selected gate lift mode (curve 2) is inside this zone, but passes too close to its boundaries. Therefore, even small deviations lead to the fact that it crosses the boundaries of the permissible zone, and the pressure behind the gates drops sharply.

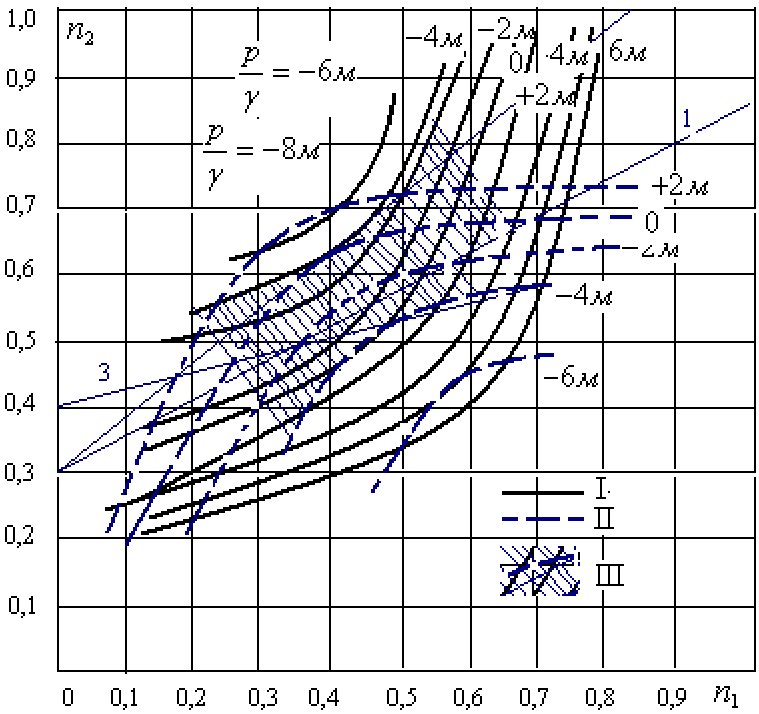

Fig. 4. Nomogram for selection of gate lift modes.

I - pressure behind the first gate; II - pressure behind the second gate; III - area of permissible pressure behind the gates.

In order to be able to reduce the requirements for the accuracy of the operation of the gates, it is necessary to choose such a scheme for maneuvering them so that the relationship curve between n_1 and n_2 passed equally distant from the boundaries of the hazardous area, for example 1 in Fig. 4. The results of calculating the effect of deviation from this newly selected schedule on the pressure behind the valves $\frac{p}{\gamma}$ are shown in Fig. 4, c (lines 3 and 4). The inaccuracy of the shutter travel in this case affects to a much lesser extent, and the requirement for the accuracy of this schedule is reduced at least two times. [7]

The new schedule requires much more advance Δt, the first shutter begins to open only when the relative opening of the second $n_2 = 0{,}3$. Thus, small openings of the second gate are excluded from the work. The lifting speed of the first shutter increases, that is, the shutter lifting time is reduced, which means that the second shutter operates for a shorter period of time in the "tail" part of the drum formed behind the first shutter. If the drive allows you to change the lifting speed, then you can slightly increase the lead (curve 3 in Fig. 4), which allows the gates to be brought closer together.

One can come to a similar conclusion - that the gates should rise at different speeds and that the distance between the gates can be somewhat reduced on the basis of experimental research [3,7]. Although the schedule for maneuvering the gates has changed slightly, the total flow rate of the water supply system, and therefore the filling time, has changed little.

If in Fig. 3 we plot the points corresponding to the values n_1 and n_2 (table), then they will be located along the axis of the permissible zone at the same distance from both boundaries.

This means that the valve lift schedule based on relation (5) is indeed optimal. In cases where relation (5) is not fulfilled, the schedule can be constructed as follows: according to a given throughput, an approximate gate lift mode is selected and trial calculations are made for this mode and 2-3 close to it. [5-8]

Then, according to the calculated data, a nomogram is constructed, similar to Fig. 6, according to which the graph of the relationship between n_1 and n_2 and the final calculation of the hydraulic characteristics of the sluice is made. This nomogram is also necessary to assess the required accuracy of the drives [1,2,5].

CONCLUSION.

With the synchronous operation of both gates, it is not possible to achieve the same pressure distribution behind the gates during the period of their opening. The first shutter should start opening with some delay and move at a higher speed than the second.

The proposed technique allows you to select a gate lift schedule, the requirement for the accuracy of which is reduced by 2 times. This significantly increases the reliability of the valves.

In the article, only flat gates were considered, however, a similar construction can be done for any other types of gates.

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