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Method For Assessing The Operating Mode Of Pump Stations In The Karshi Machine Channel Cascade And Calculating Their Hydraulic Parameters

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Abstract: First of all, the method for improving the pumping station and the anti-machine channel cascade is based on the design mode of the pumping station and the parameters of the water and channel flow, as well as the development of a hydraulic model. which characterizes the mutual dynamics of the hydraulic parameters of the pump unit and the flow of water and channel, as well as the energy characteristics of the motor pump.

Keywords: Machine channel, pumping station, water level, cascade, operating mode, hydraulic model, aggregate, hydrostation.

INTRODUCTION:

The Karshi Machine Canal cascade belongs to the class of large hydraulic structures and is a complex irrigation system, depending on the operating parameters of the water flow and the operating mode of the pumping station. The operating mode of each pumping station in the Karshi machine canal cascade is continuously dependent on the operating mode of other pumping stations in the cascade, as well as on the dynamics of the water level and flow in the canal. That is, for the operation of 5 units at the I pumping station, the water level in the channel supplying water to the I pumping station is 244.08 marks relative to the BKT (Baltic coordinate system), for the operation of 5 units at the II pumping station, the water level in the channel supplying water to the III pumping station is 258.2 marks, for the operation of 5 units at the III pumping station, the water level in the channel supplying water to the III pumping station is 282.07 marks, for the operation of 5 units at the IV pumping station, the water level in the channel supplying water to the IV pumping station is 303.46 marks, for the operation of 5 units at the V pumping station, the water level in the channel supplying water to the V pumping station is 327.27 marks, and finally, for the operation of 5 units at the VI pumping station, the water level in the channel supplying water to the VI pumping station is 350.27 marks. Consequently, the operating mode of pumping stations in the Karshi Machine Canal cascade is continuously dependent on the water level, flow rate, and the operating mode of pumping stations in each cascade.

Due to climate change and anthropogenic impacts, the water level and forvater of the Amu Darya River fluctuate sharply throughout the year. These circumstances, in turn, require the assessment of the operating mode of pumping stations in the Karshi Machine Canal cascade and the calculation of their hydraulic parameters.

Of course, foreign and Uzbek scientists have carried out a sufficient amount of research work on assessing the operating mode of pumping stations and their energy parameters.

At the same time, scientific and technical issues related to the assessment of the operating mode of pumping stations in large cascade machine canals depending on the hydraulic parameters of the water flow in the canal and the calculation of hydraulic and energy parameters have not been sufficiently studied.

Based on the foregoing, using the example of pumping stations in the Karshi Machine Canal cascade, which is the object of research, we set ourselves the goal of improving the method for assessing and calculating the operating mode of pumping stations in relation to the parameters of the water flow in the canal. To achieve this goal, we introduce the following initial parameters.

$Q_{av.d}$ – average daily water discharge, lifted by the pumping station to the next cascade;

Q_{max} – maximum water consumption required to be lifted by the pumping station within one hour;

Q_{av} – average water consumption required to be lifted by the pumping station within one hour;

Q_{min} – minimum water consumption required to be lifted by the pumping station within one hour;

$H_{\text{канал}}$ – the pressure at the hydropost required for the operation of all units at the pumping station;

H_{max} – pressure generated by units at the pumping station;

K_{min} – the minimum number of failures occurring during the operation of pumping stations during the day;

K_{max} – the maximum number of failures occurring during the operation of pumping stations during the day;

$a_{min}, a_{max},$ – technical condition of the pumping station, its units, equipment and devices, as well as the machine channel.

Now, to derive the equation of the relationship between the hydraulic parameters of the water flow and the energy characteristics of the pumping units, we write the balance equation of the projections of the acting forces on the abscissa axis in the section of the water flow bounded by sections (1-1) and (2-2) in the following form.

$$F_{in.f}+F_{fric.f}+F_R=F_{dr.f} \quad (1)$$

where: $F_{in.f}$ – m inertial force of mass water flow, $F_{fric.f}$ – friction force arising on the impellers of the pumping unit, F_R – m reactions of the mass flow of water formed in the pressure section of the pumping unit, $F_{dr.f}$ – driving forces. As driving forces, we consider the hydrodynamic pressure forces that arise during water movement.

Now, let's designate the terms in the force projection balance equations (1) with their corresponding expressions:

$$F_{in.f} = m\frac{d^2Q}{dt^2}\cdot\frac{1}{\nu} \quad (2)$$

where: m – mass of water flow, t – time, Q – pump $\left[\frac{м^3}{с}\right]$, ν – kinematic viscosity of water $\left[\frac{м^2}{с}\right]$.

$$F_{\text{ишқ}} = k_{д}\frac{dQ}{dt}\cdot\frac{1}{\nu} \quad (3)$$

where: k_d – damping coefficient during forced damping of negative vibrations occurring during the lifting of the water flow in the pumping unit $\left[\frac{нс}{м}\right]$.

$$F_R = K_M\cdot Q\cdot h_k\cdot\frac{1}{\nu} \quad (4)$$

where: K_M – volumetric compression modulus of water [Па], h_k – water flow depth in the canal [м].

$$F_{dr.f} = P\cdot\sin\omega\cdot t \quad (5)$$

where: P – hydrodynamic pressure force generated by the impellers of the pumping unit and the pressure pipe [н], ω – frequency of free oscillations of the pumping unit's impellers $\left[\frac{1}{с}\right]$, t – period of oscillation [с].

(2), (3), (4) and (5) substituting the expressions into equation (1), we obtain the following ordinary differential equation:

$$m\cdot\frac{d^2Q}{dt^2}\cdot\frac{1}{\nu}+\frac{k_{д}}{\nu}\cdot\frac{dQ}{dt}+\frac{k_m}{\nu}\cdot h_k\cdot Q = P\cdot\sin(\omega t) \quad (6)$$

(6) two sides of the equation ν hectare and we get the following equation:

$$m \cdot \frac{d^2Q}{dt^2} + k_д \cdot \frac{dQ}{dt} + k_m \cdot h_k \cdot Q = P \cdot \nu \cdot \sin(\omega t) \cdot \frac{h_н}{h_k} \qquad (7)$$

Where: $h_н$ - pressure generated by the pump unit [м], h_k – water flow depth in the canal [м], $N = P \cdot \frac{\nu}{h_k}$ – pump unit capacity [кВт] taking into account, we rewrite equation (7) in the following form:

$$m \cdot \frac{d^2Q}{dt^2} + k_д \cdot \frac{dQ}{dt} + k_m \cdot h_k \cdot Q = N \cdot h_k \cdot \sin(\omega t) \qquad (8)$$

To solve equation (8), we introduce dimensionless parameters of the form:

$$m = \bar{m}m_0\,,\, t = \bar{t}t_0\,,\, Q = \bar{Q}Q_0\,,\, k_д = \overline{k_д}k_{д0}\,,\, k_m = \overline{k_m}k_{m0}\,,\, h_н = \overline{h_н}h_{н0}\,,\, h_k = \overline{h_k}h_{k0}\,,\, N = \bar{N}N_0\,,\, \omega = \bar{\omega}\omega_0 \qquad (9)$$

Besides that $\frac{dQ}{dt} = \frac{Q_0}{t_0}\frac{d\bar{Q}}{d\bar{t}}$ ва $\frac{d^2Q}{dt^2} = \frac{d}{dt}\left(\frac{dQ}{dt}\right) = \frac{d}{dt}\left(\frac{Q_0 d\bar{Q}}{t_0 dt}\right) = \frac{Q_0}{t_0^2} \cdot \frac{d^2\bar{Q}}{d\bar{t}^2}$ equation (8) takes the following form:

$$\bar{m}m_0 \frac{Q_0}{t_0^2} \cdot \frac{d^2\bar{Q}}{d\bar{t}^2} + \overline{k_д} \cdot \overline{k_{д0}} \cdot \frac{Q_0}{t_0}\frac{d\bar{Q}}{d\bar{t}} + \overline{k_m}k_m \cdot \overline{h_k}h_{k0} \cdot \bar{Q}Q_0 = N_0\bar{N} \cdot \overline{h_н} \cdot h_{н0} \cdot \sin(\omega_0\overline{\omega \cdot} \bar{t}t_0) \qquad (10)$$

(10) two sides of the equation $\bar{m}m_0\frac{Q_0}{t_0^2}$ hectare let's split the result:

$$\frac{d^2\bar{Q}}{d\bar{t}^2} + \frac{k_д \cdot t_0}{m_0} \cdot \frac{\overline{k_д}}{\bar{m}}\frac{d\bar{Q}}{d\bar{t}} + \frac{h_{k0} \cdot k_{m0} \cdot t_0^2}{m_0} \cdot \frac{\overline{k_m h_k}}{\bar{m}} \cdot \bar{Q} = \frac{N_0 h_{н0} \cdot t^2}{m_0 Q_0} \cdot \frac{\overline{N h_н}}{\bar{m}} \cdot \sin(\omega_0 t_0 \cdot \bar{\omega}\bar{t}) \qquad (11)$$

We introduce notations into equation (11) in the form:

$$a_1 = \frac{k_{д0} \cdot t_0}{m_0};\, a_2 = \frac{h_{k0} \cdot k_{m0} \cdot t_0^2}{m_0};\;\; a_3 = \frac{N_0 h_{н0} \cdot t^2}{m_0 Q_0};\;\; a_3 = \omega_0 t_0 \qquad (12)$$

(12) all expressions are dimensionless quantities and express the criteria of hydrodynamic similarity. Including a_1-characterizing the ratio of friction forces to inertial forces $a_1 = \frac{1}{R_e}$ Represents the Reynolds criterion.

a_2 the parameter characterizes the ratio of the force causing the compression of the water volume in the working wheels of the pumping unit and the pressure pipe, depending on the dynamics of the pressure, to the inertia force.

$a_2 = Ne$ – this represents Newton's criterion.

a_3 characterizing the ratio of hydrodynamic pressure forces to inertial forces, $a_3 = E_u$ – expresses Euler's criterion.

a_4 and the parameter characterizes the Homochronism criterion, a_4=H0

Considering the above, equation (11) takes the following form:

$$\frac{d^2\bar{Q}}{d\bar{t}^2} + \frac{1}{Re} \cdot \frac{\overline{k_д}}{\bar{m}} \cdot \frac{d\bar{Q}}{d\bar{t}} + N_e\frac{\overline{k_m h_k}}{\bar{m}} \cdot \bar{Q} = Eu\frac{\overline{N h_k}}{\bar{m}} \cdot \sin(\mathrm{HO} \cdot \overline{\omega t}) \qquad (13)$$

(13) a simple differential equation is a hydraulic model characterizing the dynamics of the hydraulic parameters of the pump unit and the water flow in the channel, as well as the energy characteristics of the pump motor.

(13) To carry out a numerical experiment of the hydraulic model, we introduce the corresponding notation:

$$b_1 = \frac{1}{Re}\frac{\overline{k_д}}{\bar{m}}; \qquad b_2 = Ne \cdot \frac{\overline{k_м h_k}}{\bar{m}} \cdot \bar{Q} - Eu\frac{\overline{N h_k}}{\bar{m}} \cdot \sin(\mathrm{Ho} \cdot \overline{\omega t}) \cdot \frac{\bar{Q}}{\overline{Q_t}}$$

As a result, we get the following equation in simpler form:

$$\frac{d^2\bar{Q}}{d\bar{t}^2} + b_1\frac{1}{Re}\frac{\overline{k_д}}{\bar{m}}\frac{d\bar{Q}}{d\bar{t}} + b_2\bar{Q} = 0 \qquad (14)$$

(13) to solve the ordinary differential equation, we introduce the following initial conditions:

$$\begin{cases} \bar{Q}\,(Q) = \bar{Q}_{\text{ўр.соат}} \\ \bar{Q}\,(\bar{t_z}) = \bar{Q}_{\text{ўр.сут}} \end{cases} \qquad (15)$$

Where $\bar{Q}_{\text{ўр.сут}}$ – average daily water discharge, lifted by the pumping unit to the next cascade, $\bar{Q}_{\text{ўр.соат}}$- average water consumption required to be lifted by the pumping station within one hour. (14) from the equation $\bar{Q}$ We can rewrite the function as an exponential function:

$$\bar{Q_\iota}(\bar{t}) = \exp(\breve{N} \cdot \tau) \qquad (16)$$

Substituting the function (16) into equation (14), we obtain:

$$\breve{N^2} \cdot \exp(\breve{N} \cdot \tau) + b_1 \exp(\breve{N} \cdot \tau) + b_2 \exp(\breve{N} \cdot \tau) = 0 \qquad (17)$$

Consequently $\breve{N}$ we obtain the characteristic equation for the parameter:

$$\breve{N^2} + b_1\breve{N} + b_2 = 0 \qquad (18)$$

We find the solution of quadratic equation (18):

$$\breve{N}_{1,2} = \frac{-b_1 \pm \sqrt{D}}{2}, \quad D = b_1^2 - 4 \cdot b_2$$

Then the function (16) has the form:

$$\bar{Q}(\bar{t}) = A_1 \exp\left(\frac{-b_1+\sqrt{D}}{2}\tau\right) + A_2 \exp\left(\frac{-b_1-\sqrt{D}}{2}\tau\right) \qquad (19)$$

Taking into account the initial conditions (15), we obtain the following system of equations for the coefficients A_1 and A_2 in equation (19):

$$\left.\begin{array}{l} \bar{Q}(0)=A_1+A_2=\bar{Q}_{\text{ўр.соат}} \\ \bar{Q}(\bar{t}_1)=A_1 \exp\left(\frac{-b_1+\sqrt{D}}{2}\bar{t}_1\right)+A_2 \exp\left(\frac{-b_1-\sqrt{D}}{2}\bar{t}_1\right)=\bar{Q}_{\text{ўр.сут}} \end{array}\right\} \qquad (20)$$

We solve the system of algebraic equations (20) using the Kramer method:

$$A_1 = \frac{\Delta_1}{\Delta_0}, A_2 = \frac{\Delta_2}{\Delta_0} \qquad (21)$$

where: $\Delta_0 = \exp\left(\frac{-b_1+\sqrt{D}}{2}\bar{t}_1\right) - \exp\left(\frac{-b_1-\sqrt{D}}{2}\bar{t}_1\right)$,

$$\Delta_1 = \bar{Q}_{\text{ўр.соат}} \cdot \exp\left(\frac{-b_1 - \sqrt{D}}{2}\bar{t}_1\right) - \bar{Q}_{\text{ўр.сут}}$$

$$\Delta_2 = \bar{Q}_{\text{ўр.сут}} - \bar{Q}_{\text{ўр.соат}} \cdot \exp\left(\frac{-b_1 + \sqrt{D}}{2}\bar{t}_1\right)$$

As a result, we obtain the solution of equation (19):

$$\bar{Q}(\bar{t}) = \frac{1}{\Delta_0}\left[\left(\bar{Q}_{\text{ўр.соат}} \cdot \exp\left(\frac{-b_1-\sqrt{D}}{2}\bar{t}_1\right) - \bar{Q}_{\text{ўр.сут}}\right)\right] \cdot \exp\left(\frac{-b_1+\sqrt{D}}{2}\tau\right) + [(\bar{Q}_{\text{ўр.сут}} - \bar{Q}_{\text{ўр.соат}} \cdot \exp\left(\frac{-b_1+\sqrt{D}}{2}\bar{t}_1\right))] \cdot \exp\left(\frac{-b_1-\sqrt{D}}{2}\tau\right) \qquad (22)$$

Substituting expression (22) into function (16), we get an equation of the following form:

$$\bar{N}\tau = \ln\left\{\left[\left(\bar{Q}_{\text{ўр.соат}} \cdot \exp\left(\frac{-b_1-\sqrt{D}}{2}\bar{t}_1\right) - \bar{Q}_{\text{ўр.сут}}\right)\right] \cdot \exp\left(\frac{-b_1+\sqrt{D}}{2}\tau\right) + \left[\left(\bar{Q}_{\text{ўр.сут}} - \bar{Q}_{\text{ўр.соат}} \cdot \exp\left(\frac{-b_1+\sqrt{D}}{2}\bar{t}_1\right)\right)\right] \cdot \exp\left(\frac{-b_1-\sqrt{D}}{2}\tau\right)\right\} - ln\Delta_0 \qquad (23)$$

Equation (23) represents the electrical energy consumed by the pumping unit during one unit of time to lift one unit of water mass to the upper cascade.

2-table

Experimentally determined values of the energy and hydraulic parameters of the pumping station and its units in the Karshi machine channel cascade.

№	Pumping Station Name	Aggregate number, pieces	Water discharge capacity 1 pumping unit m³/sec	Q_{max} mln.m³/day	$Q_{ўр}$ mln.m³/day	Q_{min} mln.m³/day	$H_{кан}$ м	$H_{нс}$ м	El/energy consumed per day, kWh
1	1-PS	3	36	14,6	12,1	8,6	6,7	17,9	14,4
		3 (1,3,4 ar)	39						
2	2-PS	6	36	14,2	11,7	8,2	5,7	22,6	14,0

3	3-PS	6	36	13,9	11,4	7,9	5,6	22,4	13,8
4	4-PS	6	36	13,7	11,3	7,8	6,4	22,2	13,5
5	5-PS	6	36	12,3	8,7	7,7	6,1	23,5	9,7
6	6-PS	6	36	11,8	8,3	7,3	6,8	23,6	9,5

3-table

Information on the volume of water lifted by pumping stations in the cascade of the Karshi Machine Canal

№	НС номи	2022 йил (*млн.м*^{3})									
		I	II	III	IV	V	VI	VII	VIII	IX	Жами
1	НС-1	263,9	299,5	360,8	415,5	437	456,4	422,4	347,9	259,1	**3262,5**
2	НС-2	253,1	289,3	350,2	403,7	424,8	444,2	410,4	335,6	246,2	**3157,5**
3	НС-3	245,8	281,9	342,3	394,9	415,7	435,1	401,1	327,2	237,8	**3081,8**
4	НС-4	241,9	278,3	338,1	390,8	411,4	430,8	395,9	319,9	232,8	**3039,9**
5	НС-5	240,3	268,6	184,1	296,8	367,5	315,5	189,7	243,8	230,3	**2336,6**
6	НС-6	232,4	259,8	172,8	283,8	353,3	302,4	176,2	231,9	219,8	**2232,4**
7	НС-7	175,8	201,3	0	1	226,3	106,3	0	48,9	133,1	**892,7**
	Жами	**1653**	**1879**	**1748**	**2187**	**2636**	**2491**	**1996**	**1855**	**1559**	**18003,4**

We conduct a numerical experiment of expressions (22) and (23) based on the results of the experiment presented in Tables 2 and 3. Comparative graphs of numerical and field experiments are shown in Fig. 1-4. The comparison error averages 5 percent.

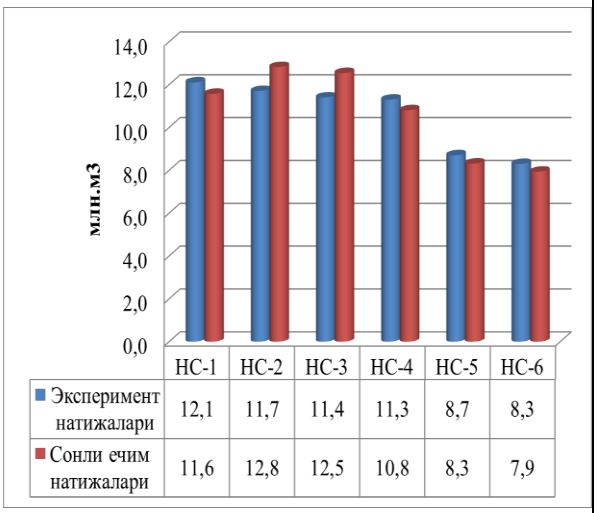

Figure 1. Average daily volume of water raised by pumping stations in the cascade of machine canals

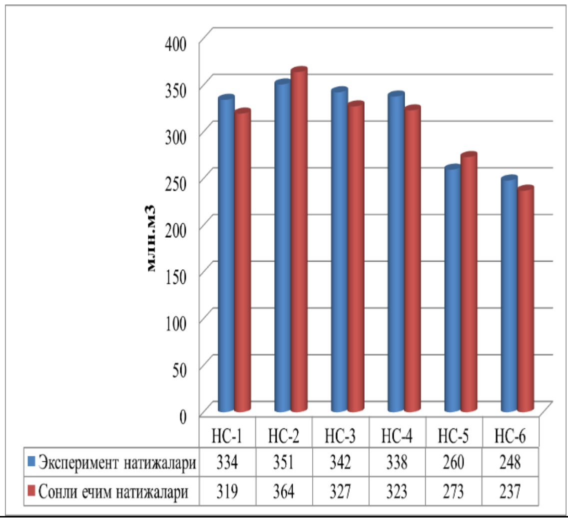

Figure 2. The volume of water raised by pumping stations in a cascade of machine canals on average per month.

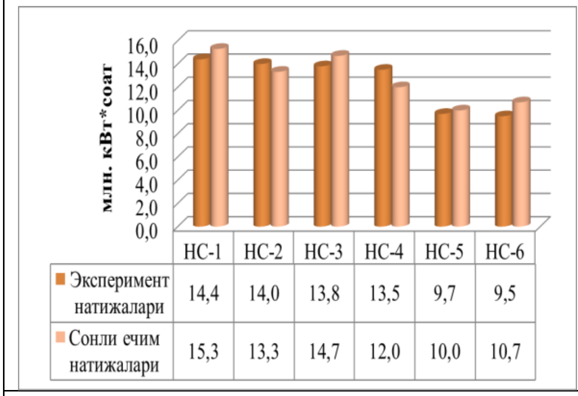

Figure 3. Electricity consumed by pumping stations in the cascade of machine channels to raise the average daily water volume.

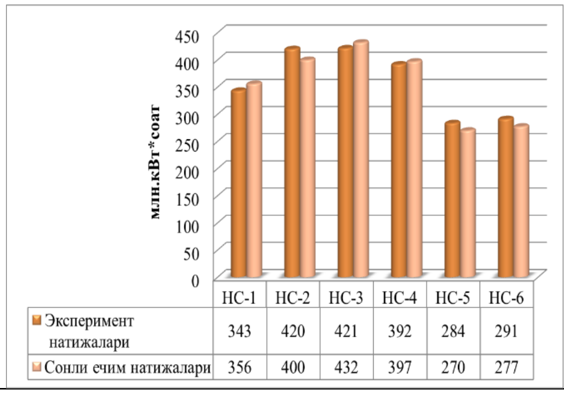

Figure 4. Electricity consumed by pumping stations in the cascade of machine channels to raise the water volume on average per month.

CONCLUSION

Using the example of pumping stations in the Karshi machine canal cascade, based on the Reynolds, Newton, Euler, and Homochronism criteria, a hydraulic model was developed that characterizes the dynamics of the hydraulic parameters of the pumping unit and the water flow in the canal, as well as the energy characteristics of the pumping motor.

REFERENCES

1. A Zh Seitov, BR Khanimkulov. Mathematical models and criteria for water distribution quality in large main irrigation canals. Academic research in educational sciences. Uzbekistan. Ares.uz. Vol. 1. №2, 2020. ISSN 2181-1385. Pp.405-415. (№5, web of science IF=5.723)
2. **Roziyev, M.O.** *"Mathematical Model of Unsteady Water* Flow Occurring in the Counter-Machine Channel Depending on the Operating Mode of the Pumping Station.*"* **Khorezm Mamun Academy Bulletin**, No. 2024-6/1, pp. 236–239.
3. **Roziyev, M.O., Mahmudov, I.E., Murodov, N.Q.** *"Survey and Assessment of the Water Resources Status of the Country's Main Canal."* **Academic Research in Modern Science**, 2024, pp. 111–115.
4. **Roziyev, M.O., Murodov, N.Q., Narziyev, J.J., Jovliyev, U.T., Shonazarov, J.Yo.** *"Experimental Investigation of the Energy Characteristics of Pumping Stations and Hydraulic Parameters of the Canal in the Cascade of the Qarshi Machine Canal."* In: **International Scientific-Practical Conference "Current State and Prospects of Mitigating the Consequences of Global Climate Change and Water Scarcity."** Karshi Institute of Irrigation and Agrotechnologies, TIIAME NRU, 2024, pp. 439–441.