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Purification Of The Settling Chamber Of A Pumping Station From Silt Sediments Using A Slurry Pump

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Abstract: This paper discusses one of the operational challenges faced by pumping station forechambers during exploitation: the cleaning of silt deposits from the bottom of the structures. A scheme for a silt cleaning device designed to remove silt deposits from the bottom of the forechamber using a slurry pump is proposed. The device transports the silt mixture through the pumping station's pressure pipeline to an upper reservoir, from where it is then distributed to irrigation fields. A methodology has been developed to determine the key pressure-water consumption parameters and the energy performance indicators of the silt cleaning device. Calculations performed using this methodology indicate that when this device is used to clean silt deposits in the forechamber, the total energy consumption of the pumping station is only 0.051% for cleaning 30 cubic meters of silt.

Keywords: Pumping station, forechamber, slurry pump, silt deposits, pressure pipeline, hydraulic mixture, pressure characteristics, operating point.

Introduction

In irrigation pumping stations, during the months of March and April, before the main period of vegetation begins, the high amount of silt in the water leads to the formation of thick silt layers at the bottom of many station forechambers. This situation disrupts the hydraulic structure of the flow, negatively impacts the operation of the pumping station, reduces the efficiency of water supply, and decreases the pump's coefficient of performance [1,2,3]. Silt deposit cleaning operations are not typically conducted during the vegetation period in most pumping stations. As a result, they are forced to operate with low efficiency throughout the vegetation period, leading to excessive electrical energy consumption in the pumping stations.

The cleaning of silt deposits from the forechamber of reclamation pumping stations is primarily conducted during repair periods of the pumping station, outside the vegetation period. Dredgers, excavators, other machinery, and manual labor are used for this purpose, with costs ranging from 50 to 500 million soms, according to the Republic Water Management Ministry's data. Another method for cleaning silt deposits from the forechamber involves using slurry pumps designed for pumping silt, pulp, and other viscous liquids. A new device based on this method, allowing for the cleaning of silt deposits from the forechamber even while the pumping station is operational, has been proposed (Figure 1) [4,5,6].

This device uses a slurry pump to transfer the silt deposits accumulated in a special pit within the forechamber to the pressure pipeline of the pumping station. The primary advantages of using a slurry pump to remove silt deposits from the forechamber of the pumping station are as follows:

a) Silt particles are discharged to the upper reservoir without entering the pump unit's water flow section, thereby protecting the pump components from hydroabrasive wear.

b) The method allows for the discharge of an additional amount of water along with the silt particles, which is particularly beneficial after the silt deposits are cleaned, as the slurry cleaning pump can be used to regulate water flow.

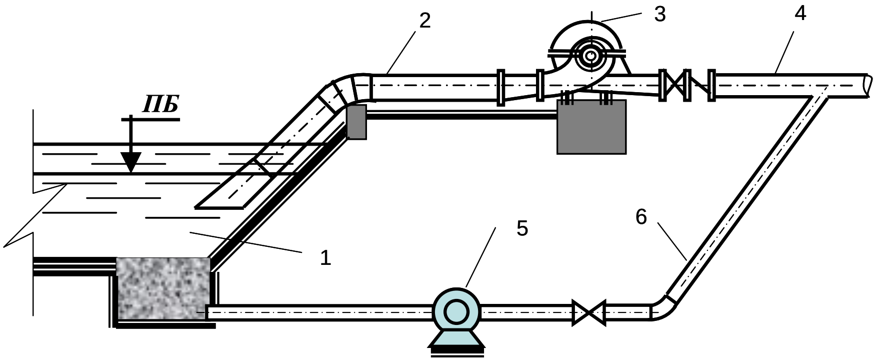

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Figure 1. Device for cleaning the forechamber of silt using a slurry pump

c) This device can also be used to protect the pumping station equipment from hydraulic shocks. The proposed device can prevent a sharp increase in pressure during the hydraulic shock caused by the closure of the non-return valve in the pump unit.

It should be noted that this device is used only when necessary, i.e., when the pit in the forechamber is filled with silt. Consequently, the energy consumption for the silt cleaning pump is not significant due to the short operating time of the device[7,8,9].

Methods and Materials

To determine the operational parameters of the silt cleaning device using a slurry pump for cleaning silt deposits in the forechamber, we will construct the operating mode graph of the device and pump unit (Figure 2).

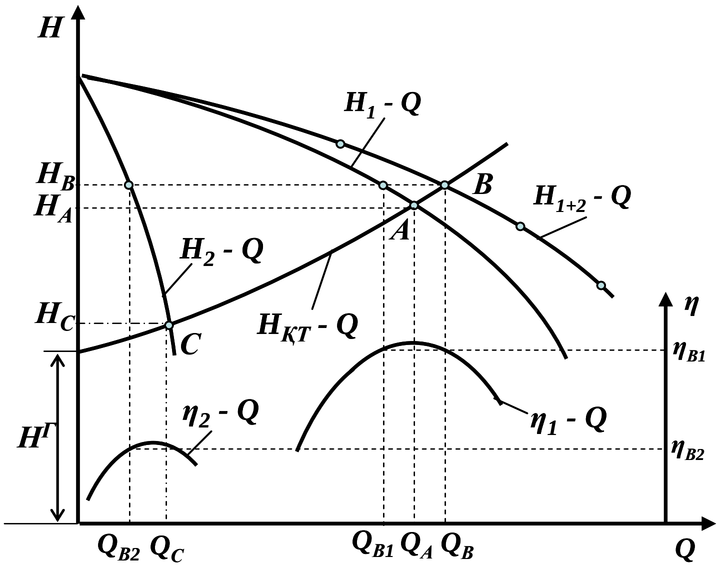

Figure 2: Operating mode graph of the pump unit and slurry pump working together

The silt cleaning pump operates independently when the hydro mixture is discharged into the pressure pipeline, where Q_C represents the flow rate of the hydro mixture and H_{QT} represents the head of the main pump. At the point of operation for the main pump and silt cleaning pump together, the characteristic of the pump system is determined by the H_Q - Q curve, where point C denotes the operating point of the pump system, characterized by the head H_{QT} and flow rate Q_C. Similarly, the operating point of the main pump, denoted by point A, has the same head as point C but a different flow rate.

$$Q_{\text{B}} = Q_{\text{B1}} + Q_{\text{B2}} = Q_{water} + Q_{\text{B1}} + Q_{silt} \quad (1)$$

The silt cleaning pump must be capable of providing the following power during operation.

$$N_{silt} = 9{,}81 \cdot Q_{\text{B2}} \cdot H_{\text{B}} / \eta_{\text{B2}}, \ \text{kW} \quad (2)$$

The required amount of electrical energy for the operation of this pump is as follows.

$$Э_{silt} = N_{silt} \cdot \text{T}_{silt} \quad \text{kW*h} \quad (3)$$

here T_{silt} – the operating time of the silt cleaning pump, in hours.

The pump unit, together with the silt cleaning pump, is required to provide the following power to pump the amount of silt-laden water.

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$$N_B = 9.81 \cdot Q_B \cdot H_B / \eta_B \qquad (4)$$

The pump efficiency is determined as follows: $\eta_B = \dfrac{(Q_{B1} + Q_{B2}) \cdot \eta_{B1} \cdot \eta_{B2}}{Q_{B1} \cdot \eta_{B2} + Q_{B2} \cdot \eta_{B1}}$ (5)

As observed from the graph in Figure 2, the simultaneous operation of the silt cleaning pump with the main pump reduces its water delivery efficiency by the amount Q_A - Q_{B1}. Additionally, an additional amount of water $Q_{water} = Q_B - Q_{B1} - Q_{silt}$ is supplied to the pressure pipeline simultaneously. Consequently, there is no significant change in the water delivery efficiency of the pumping station.

Results and Discussion:

The impact of using a silt cleaning pump on the operational parameters of the pumping station can be illustrated through the following example:

Suppose a pumping station's forechamber, equipped with a pump unit utilizing the D1600-90M-0 model pump, requires silt cleaning. To meet this demand, a silt cleaning pump with the specifications of the GrAT 85/40/I-1.6 model, with a rotational speed of 1450 rpm, a flow rate of 85 m^3/s, a head of 40 m, a power of 15 kW, and a density of 1.6 t/m^3 for the silt, is selected.

Analyzing the operating regime of the D1600-90M-0 pump in conjunction with the silt cleaning pump using graphical methods yields the obtained results, as depicted in Figure 3.

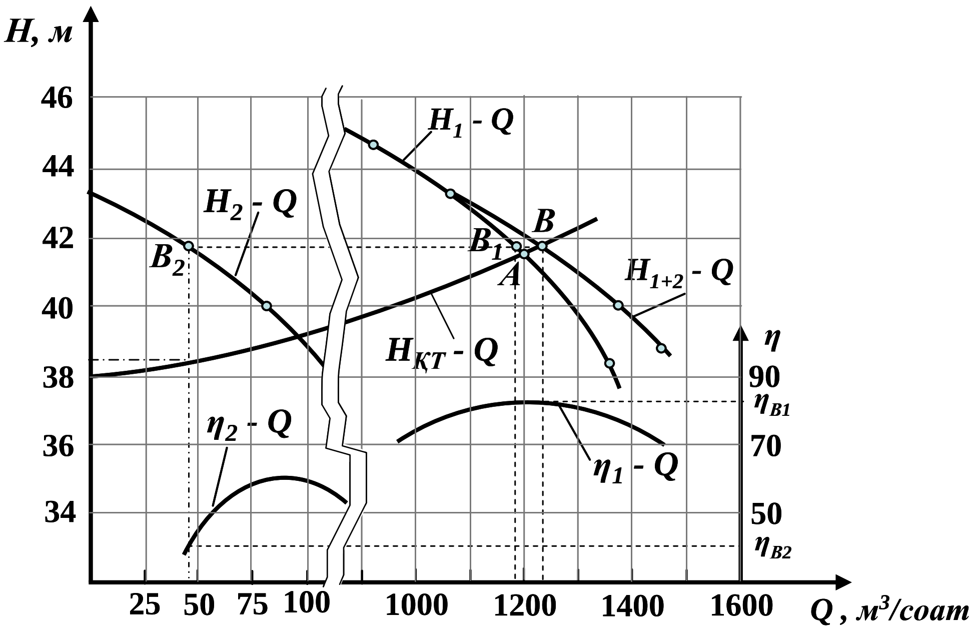

Figure 3: Graphs of the operating regimes of the D1600-90M-0 pump and the GrAT 85/40/I-1.6 silt cleaning pump.

From the graph, it can be observed that the combined operation of the pumps yields the following indicators:

$Q_B = 1230$ м³/hour, $Q_A = 1200$ м³/hour, $Q_{B1} = 1185$ м³/hour, $Q_{B2} = 38$ м³/hour, $H_B = 41{,}8$ *м*, $\eta_{B2} = 40\%$, $\eta_{B2} = 82\%$, $H_A = 41{,}6$ *м*, $\eta_A = 83\%$

Therefore, when both pumps operate together, the total power requirement for them is equal to the following value.

$$N_B = 9{,}81 \cdot Q_B \cdot H_B/\eta_B = 9{,}81 \cdot 0{,}342 \cdot 41{,}8/0{,}79 = 177{,}32\ kW$$

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here, $$\eta_B = \frac{(Q_{BI} + Q_{B2})\eta_{B1} \cdot \eta_{B2}}{Q_{B1} \cdot \eta_{B2} + Q_{B2} \cdot \eta_{B1}} = \frac{(1185 + 38) \cdot 0{,}82 \cdot 0{,}4}{1185 \cdot 0{,}4 + 38 \cdot 0{,}82} = 0{,}79$$

calculate the power of the purification pump.

$$N_{B_2} = 9.81 \cdot Q_{B2}.H_B/\eta_{B2} = 9{,}81 \cdot 0{,}0105/0{,}4 = 10{,}81\,kW$$

The installed power of the pump unit corresponds to the standard value of 15 kW with the efficiency coefficient.

During the operational period of the pump station, when purification activities are carried out for 2 hours starting from the 20 times, the amount of electrical energy consumed for this task is as follows.

$$Э = N \cdot T_{silt} = 15 \cdot 40 = 600\,kW \cdot h$$

So, at an electricity rate of 1000 Uzbekistani som per kilowatt-hour, the cost of purification amounts to 600,000 som. This constitutes 1.2% of the total expenses, which amount to 50 million som for utilizing land excavation mechanisms in the purification process.

When the pump unit in the pump station operates for 2400 hours annually, the electricity consumed can be calculated as follows.

$$Э_{HC} = N_A \cdot n \cdot T_{hour} = 163{,}9 \cdot 3 \cdot 2400 = 1180080\ kW \cdot h$$

Here $N_A = 9{,}81 \cdot Q_A \cdot H_A/\eta_A = 9{,}81 \cdot 0{,}33 \cdot 41{,}6/0{,}83 = 163{,}9\ kW$

So, the amount of electrical energy consumed for the purification pump constitutes a mere 0.051% of the total energy usage.

In conclusion, it's evident that the operation of the purification pump within the pump station does not significantly impact the operational indicators of the station and does not incur substantial expenses. Moreover, in cases where the hydro-area consists of partially waterlogged areas, the purification pump, with its additional capacity of 15 m^3/hour, provides the capability to extract water. In such scenarios, the extraction of water by the pump contributes not only to maintaining the pressure in the pumping station's supply system but also potentially increases its efficiency[10,11].

Conclusion

1. A graphoanalytic methodology has been developed to determine the pressure-water consumption parameters and energy indicators of the soil purification unit assisted by a ground pump.

2. When utilizing the soil purification unit with a ground pump, the total electrical energy consumption of the pump station amounts to only 0.051%, while the expenses for soil purification with excavation mechanisms may constitute 0.5% to 1.5%.

3. The utilization of the soil purification unit ensures that the volume of purified water remains consistent, as the ground pump facilitates the extraction of water, thereby maintaining the efficiency of the pump station's water supply system.

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