

The forces acting on the teeth of catching machine

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Abstract. Republic of Uzbekistan, pumping stations are used in very difficult conditions. The presence of various particles and effluents in the water has a negative effect on the operating modes of the pumping equipment. Special grilles are installed to prevent the catching devices from entering the advance chamber of the pump station. The shape and length of the device covers are of great importance so that they are caught in front of the grilles and completely cover the accumulated debris. In the article, the laws of mechanics were used to determine the shape and size of the working device of the device for cleaning the effluent flowing into the pump station as water and accumulated in front of the grids. In doing so, the condition of ensuring complete removal of the leaks covered by the device was taken into account. It was argued that the angle γ between the working surfaces and velocities of the covers should be less than $90-\varphi$ over its entire working surface in order to fully cover the device shafts. It was found that when the working surface of the device is flat, the time of interaction with the catching device pieces is minimal. Studies and literature have shown that the angle of friction on the working surfaces of the device covers should be $\varphi=20^\circ$, the angle between the working surface of the device cover and the rotational speed $\gamma=70^\circ$.

Keywords. Pump station, fore chamber, cage, mouth, device, suction pipe, cavitation.

1 Introduction

Extremely turbid water in the country's sources, parts of pumping units that carry water, including bodies, substances, effluents, including impellers, fail mainly due to mechanical effects and cavitation erosion [1, 2]. It is necessary to ensure the geodetic suction height of the water level in the avant-garde to prevent cavitation erosion that occurs on the working blades of the pump unit. In cases where the water is clean and flows at the same flow rate without obstruction, the suction height in the vane chamber can be ensured [3-5]. Russian Scientists from the Siberian State Technological University, V.P. Korpachev and A.I. Perezhilin, studied the causes of water pollution in hydropower plants and recommended that reservoirs should be kept clean, mainly due to leakage of water from the shores [6].

In 2016-2020, research work showed that on the Amu-Bukhara canal, the Karshi main canal,

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the drop in water level in the avalanche occurred as a result of changes in water consumption in the Amudarya, the muddy filling of canals and the formation of artificial barriers [7, 8].

The change in the period and volume of discharge of effluents from the Amudarya to the pumping stations depends on the following [9]:

- at the beginning of the irrigation season to the time of the first supply of water to the pump station;
- the amount of tree stems, roots, which are washed away due to the increase in water consumption in the river, the water changes its course and flows with it;
- the type of waste generated by industrial, manufacturing and domestic organizations located along rivers and canals;
- due to the location of pastures and meadows along the coast, the animals can accidentally fall, drown and flow to the pumping stations.

Fences have been installed in the Amu-Bukhara-1 and Amu-Bukhara-2 car canals to trap water leaks and prevent it from entering the pumping station (Fig. 1).



Fig. 1. The process of removing debris collected in front of the grate at the pump station Amu-Bukhara-1: 1 – mouth; 2 – grid holding traps; 3 – streams falling back into channel; 4 – car moving rails; 5 – dryer cover; 6 – the machine that moves the cleaning device.

The different nebulae of the runoff, the rapid change in size throughout the year, and the erratic flow in different directions cause the water to accumulate in front of the installed fences and block the waterway (Fig. 2).



Fig. 2. Collection of effluents in front of the grate at the Amu-Bukhara-2 pumping station: 1 – mineral and organic particles; 2 – water access paths to the forechamber.

At the Amu-Bukhara-1 and Amu-Bukhara-2 pumping stations, one of the main reasons for the drop in the water level in the vane chamber was the failure of the device to fully meet the requirements [10, 11]. As a result of untimely cleaning of the gutters in front of the fences installed in front of the van, the water became stagnant, which led to a drop in the water level in the van.

A drop in the water level in the vane chamber creates water clusters in front of the suction pipes, which leads to the absorption of air into the pump and a decrease in performance [12, 13].

Therefore, the improvement of the technology of cleaning and removal of debris is one of the important issues. The aim of the study was to substantiate the parameters of the device workstation, which provides for the cleaning and removal of debris accumulated in front of the grilles (Fig. 3). The following issues have been resolved to achieve this goal:

- to determine the forces acting on the device covers to ensure that the debris accumulated in front of the grille is completely covered and removed;
- to determine the shape of the cover to ensure complete removal and removal of debris that has accumulated in front of the grilles [14].



Fig. 3. The process of covering the mouths: 1 – device base; 2 – device base wheels; 3 – grid holding traps; 4 – a set of mouthpieces with different contents.

2 Method

The forces acting on it were determined using the laws of mechanics to determine the shape and size of the work piece of the device that cleans the debris that flows into the pump station avanker along with the water and accumulates in front of the grilles. In doing so, the condition of ensuring complete removal of the leaks covered by the device was taken into account.

3 Results and discussion

The shape and length of the device covers are of great importance so that they are caught in front of the grilles and completely cover the accumulated debris. To ensure that the lugs that have accumulated in front of the grilles are completely covered and cleaned, we will first consider the forces acting on the lugs by the device lining. During the process of covering the device shafts, its M part is affected by normal N and frictional forces F by the device cover (Fig. 4). We divide the normal force N acting on the M part of the catching device into two influences: the device velocity V_m in the process of covering the catching devices, i.e., N_v directed along its rotation speed relative to point 0, and N_τ directed along the working surface of the catching device [15-19]:

$$N_\tau = N_{ctg} \gamma \tag{1}$$

and

$$N_v = \frac{N}{\sin \gamma}, \tag{2}$$

where γ is the angle between the working surface of the device cover and the rotational speed V_M . For the catching devices to be completely covered by the device cover, the force N_τ must be greater than the friction force F , i.e.

$$N_\tau > F. \tag{3}$$

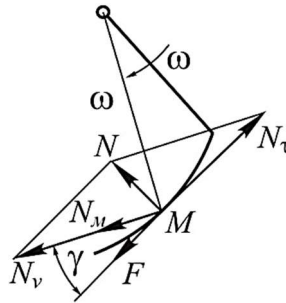


Fig. 4. A diagram of the forces acting on the parts of the mouthpiece by the cover of the device cover.

This is because only when this condition is met it is ensured that the catching devices are pushed upwards along the covers of the device cover, which are completely covered by the device. (3) Substituting the value of N_i in the expression (1) and taking into account that $F = fN = N \operatorname{tg} \varphi$ (where f , φ is the coefficient of friction and angle of friction on the working surfaces of the device covers, respectively), we obtain the following result:

$$N_{ctg \gamma} > N_{tg \varphi}. \tag{4}$$

We solve this expression with respect to τ :

$$\gamma > 90 - \varphi. \tag{5}$$

Hence, in order to fully cover the device surfaces, the angle γ between the working surfaces and velocities of the device covers must be less than $90 - \varphi$ over its entire working surface, i.e., condition (5) must be met. We now move on to justify the shape of the working surfaces of the device cover covers. In solving this problem, we proceed from the condition that the time of interaction between the working surface of the cover and the parts of the mouth is minimal [20-29]. This is due to the fact that, firstly, the sheets are easily moved along the working surface, and secondly, the technological process is carried out with minimal energy consumption. Let us consider the motion of the axial segments in the ZOZ coordinate system (where the OX axis is horizontal and the OZ axis is perpendicular) under the influence of the coverage, whose working surface has an arbitrary curved shape (Fig. 5).

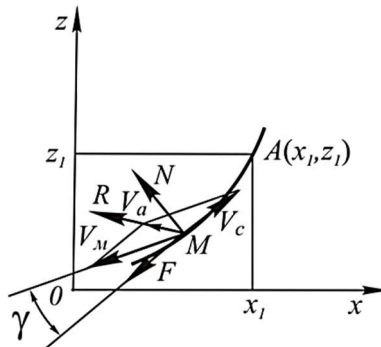


Fig. 5. The shape of the working surfaces of the device covers justification scheme.

In this coordinate system, the axial fragments rotate under the influence of the normal N and friction forces acting on them, V_m , and the relative sliding motion V_c with velocity along the working surfaces of the overlaps [1-2].

It is directed along the force R , which is an equal effect of the forces F .

In this case, the absolute velocity of the axial fragments V_a is equal to the geometric sum of the velocities V_m and the relative V_c velocities, i.e. $V_a = \sqrt{V_m^2 + V_c^2 - 2V_m V_c \cos \gamma}$ and N and it is directed along the force R , which is an equal effect of the forces F . Using the scheme shown in Fig. 5, we express the velocity V_c in terms of velocity V_m and determine the slip time t from point 0 (0.0) to the point $A(x_l, z_l)$ of the working surface of the device cover of the slice M :

$$V_c = V_m \frac{\cos(\gamma + \varphi)}{\cos \varphi} = V_m (\cos \gamma - \sin \gamma \operatorname{tg} \varphi); \tag{6}$$

$$t = \int_0^{x_l} \frac{\sqrt{dx^2 + dz^2}}{V_c} = \int_0^{x_l} \frac{\sqrt{1 + (z')^2}}{V_m (\cos \gamma - \sin \gamma \operatorname{tg} \varphi)} dx. \tag{7}$$

Assuming that the device covers are oriented V_m horizontally in the process of covering the gaps, we express the \sin and \cos in expression (7) by dx and dz :

$$\sin \gamma = \frac{dz}{\sqrt{dx^2 + dz^2}} = \frac{z'}{\sqrt{1 + (z')^2}} \tag{8}$$

and

$$\cos \gamma = \frac{dx}{\sqrt{dx^2 + dz^2}} = \frac{1}{\sqrt{1 + (z')^2}}. \tag{9}$$

Given these expressions, expression (7) has the following appearance:

$$t = \frac{1}{V_m} \int_0^{x_l} \frac{1 + (z')^2}{1 - z' \operatorname{tg} \varphi} dx. \tag{10}$$

We examine this expression to the extremum under the following condition:

$$\frac{d}{dx} (F_{z'} + F_z) = 0, \tag{11}$$

where $F_{z'}$ and F_z are specific derivatives of the function F on z' and z , respectively; F – (11) function under the integral of the expression.

(11) function under the integral according to the expression:

$$F \frac{1 + (z')^2}{1 - z' \operatorname{tg} \varphi}. \tag{12}$$

It can be seen from this expression that the function F does not depend on z . Therefore, expression (11) has the following appearance:

$$\frac{d}{dx} F_{z'} = 0 \tag{13}$$

To fulfill this condition should be:

$$F_{z'} = \frac{\partial F}{\partial z'} = \operatorname{const}; \quad \frac{d}{dx} F_{z'} = 0 \tag{14}$$

Because only then the condition is fulfilled. Taking a special derivative of z' from expression (12), we obtain the following.

$$\frac{\partial F}{\partial z'} = \frac{2z'(1 - z' \operatorname{tg} \varphi) + [1 + (z')^2] \operatorname{tg} \varphi}{(2 - z' \operatorname{tg} \varphi)^2}. \tag{15}$$

According to the expression (14), this expression must have a constant size, as such where C is a constant quantity:

$$\frac{2z'(1 - z'tg\varphi) + [1 + (z')^2]tg\varphi}{(2 - z'tg\varphi)^2} = C, \quad (16)$$

decomposing the expression (16) with respect to z , it is generally written as follows:

$$z' = f(\varphi) = const. \quad (17)$$

This expression indicates that in order for t to have an extreme value, $z' = const$ the device cover must have a flat working surface, as only that is ensured.

When the working surface of the device covers is flat (7), the expression will have the following appearance:

$$t = \frac{\ell_T}{V_m(\cos\gamma - \sin\gamma g\varphi)}, \quad (18)$$

where ℓ_T is the length of the working surfaces of the device covers.

Therefore, based on the above, it can be said that in order to ensure the quality of the technological process at the required level with low energy consumption, the working surface of the device cover should be in the form of a flat surface installed at an angle of less than $90-\varphi$ to the horizon.

In our study and in the literature, it was found that when the $\varphi=20^\circ$ is, the expression (5) should be $\gamma=70^\circ$.

4 Conclusion

The presence of various particles and effluents in the water adversely affects the operating modes of the pumping equipment. Special grids will be installed in the channel to prevent the contents of the water from entering the advance chamber of the pump station. The shape and length of the device covers are of great importance so that they are caught in front of the grilles and completely cover the accumulated debris. The correct selection of the shape and size of the workpiece ensures complete removal of the catching devices covered by the device. When the angle g between the working surfaces and velocities of the device covers is less than $90-\varphi$ over its entire working surface, it is theoretically justified that the gaps accumulated in front of the grids are completely covered. One of the main conditions is that full coverage and cleaning is ensured when the interaction time of the catching device set with the device cover, where the working surface is flat, is minimal. Studies and literature have shown that the angle of friction between the working surfaces of the device covers should be $\varphi=20^\circ$, the angle between the working surface of the device cover and the rotational speed $\gamma=70^\circ$.

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