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ENERGY CAPACITY DETERMINING OF SEDIMENT CLEANING FROM CONCRETE-LINED CHANNELS BASED ON REAL INDICATORS

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Abstract- The paper is devoted to determining the energy capacity of cleaning sediments from concrete-lined channels based on real indicators. The working body built on the excavator is a passive ladder-shaped hoe, with which it is possible to clean the bottom of concrete-lined canals, and the bottom and slope of earthen canals. The researches show that the current methods used in the cleaning irrigation channels are much efficient for cleaning soil and concrete covered channels with wide bucket excavator. The wide-pitch scoop is able to clean the channel from sediments and weeds without damaging the concrete cladding. The advantages of this method are the possibility of removing large and solid parts from the channel, the high-level mobility of the base machine, the low specific energy capacity (kW/m^3) and the others. Providing the hoe with a wide blade reduces cutting resistance and power consumption along the length of the hoe. On the back of the blade, two symmetrical rollers are attached to the hoe's knot. Depending on the state of the sediment, the drilling resistance has been studied in situations where the working body is set up with rollers.

Keywords: Concrete Channel, Channel Cleaner, Ladder-Type Hoe, Resistance Force, Energy Consumption, Sediment.

1. INTRODUCTION

During the period of operation of irrigation channels, siltation occurs for various reasons, which leads to a shortage of water in irrigated areas with a decrease in the submersible capacity of the system. And this impedes significantly the implementation of the policy pursued by the government in the development of Agriculture in the Republic by complicating the work of farmers-owners of small land plots transferred to private ownership after the land reform.

When irrigation channels are not properly carried out, their condition is negatively affected. Another problem that complicates the efficiency of the use of the irrigation network is contamination with vegetation layer and sediment inside it, as well as in its berm. All measures against water [1] loss in irrigation systems is of great importance, especially in our country. A special measure taken against water loss is the coating inner surface of the channel with special materials (concrete, asphalt - concrete, bitumen, special clay, etc.) on the. The project does not envisage contamination of concrete-lined channels. Nevertheless, the silt layer formed by erosion from various effects in the channels and later turning into sediment requires the cleaning of the canal. Recently, the construction of on-farm and Inter-farm channels with concrete cladding has been preferred, since the leakage of water in the earthen channels leads to water loss and salinization of the surrounding areas. However, in absence of proper care of concrete-lined irrigation channels during operation, silting and weeding occur in them.

Dragline type tools and soil suction devices such as rotary excavators, single bucket and multi bucket excavators, milling excavators are used for the purification process of soil channels from different sediments and plant waste. But while cleaning of concrete cladding channels, it causes crumbling of concrete layers, and the quality of process decreases. In channel cleaning, rotary, profiling, hydraulic, mechanical (with active and passive working bodies) and other cleaning methods have certain advantages and disadvantages. They do not correspond to real and sediment conditions so do not meet the demand.

As a result, the quality of channel cleaning decreases, and the cost increases 2-3 times up and becomes more expensive than earthworks performed under normal conditions. However, in the case of concrete lining channels this problem experiences usually much lower than the required level. For example, an excavator-type multi-bucket channel cleaner can only be used in channels up to 3 m wide (<3 m) from above, does not take large parts, the removal of solid sludge from the pit is delayed, but can be used on slopes, a crane is required to connect the tracks, move them to the other side of the channel, perform additional operations, such as a preliminary planning of the path of both tracks. In addition, this machine is used in channels with concrete lining less than 3 m wide (B<3 m) on top while applying, the blades rub against the concrete lining, get stuck in the seams, the blades fail and damage the lining.

The rotary method is not effective in reed, shrubby, coarse-grained, low and high-water channels and has many disadvantages. Hydraulic method of cleaning concrete channels separately and along with scratching as well as mechanical method is applied in certain countries, but it did not justify itself in production [16].

Channel cleaning machines should be able to meet the following requirements:
1) the general construction machinery used in the cleaning of the channel should be relatively more productive;
2) it must have the necessary conductivity to move along the berth or the bottom of the channel;
3) it should restore the draft size of the channel, whether bottom and slopes are correct;
4) it should provide cleaning of the channels with different depths, slopes and bottom sizes;
5) should be able to clean the bottom and slopes of the channel separately and, if necessary, clean the entire cross-sectional perimeter;
6) he must scatter the ground and weeds, which he removes from the inside of the channel, equally outward from the brow of the channel;
7) in Peaty and mineral soils, the work of cleaning the channel should be provided in the presence and absence of water and weeds inside the channel, even in cases where there are stone and wood residues.
Dragline-type excavators and soil suction devices are used in the cleaning of large channels. It is not possible to use machines for channels with concrete lining. Therefore, less powerful, lighter and more productive machines should be used for cleaning such channels [6].

Let's consider the problems of cleaning channels with a crashing laminated working body. There are many unknown factors affecting production processes, machine performance and cleaning quality when cleaning channels from sediments by a passive wide-area staircase-type working body. Since the physical nature of their connection with the working tool is unknown, defects arise in the form of the working tool and the production technology [5]. This is the distribution of forces of mutual resistance between layered precipitation, the main factors of which are their nature, the influence of the plastic profile on the resistance to drilling and the hardness of the crushed stone on the productivity of the machine, the quality of work [14, 15].

In order to achieve the goal, the model of the newly designed ladder-type hoe was tested in laboratory conditions, as well as the ability to work with different sediments, dry, semi-solid and plant remains, forces and stresses depending on the condition of the sediment, including clean cutting of the sediment depending on its thickness, stratification during cutting along the slope curve while climbing action is clarified. Depending on the condition of the sediment, the drilling resistance was studied in situations where the working body was set up with rollers in Figure 1.

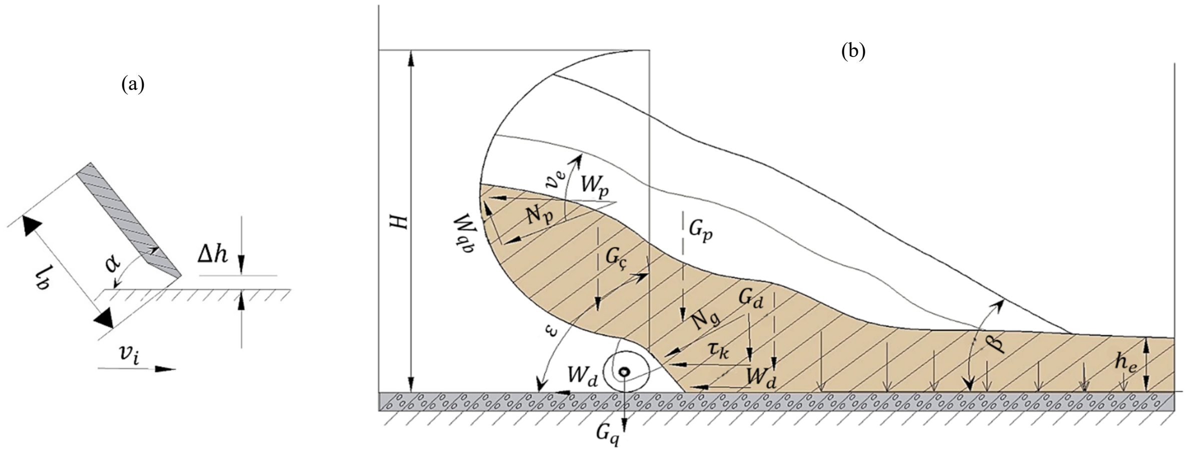

Figure 1. The cheme of the interaction between the sedimentary layer and the hoe for $h_1 > h_b \sin\alpha$ (the layer swells)
(a) is the position of the angle, (b) is the calculation scheme of the drill

An efficient machine for cleaning channels [8] is a wide-handled hoe excavator. It was determined that depending on the state of the sediments and the conditions of the drilling (underwater, in a waterless channel), the physical nature of the connection between the hoe and the sedimentary layer and the calculation scheme changes. In the present article, the energy capacity of the excavation of caked sediments in a concrete-lined waterless canal with a special hoe excavator is calculated. When excavating plasticized sediments in a waterless channel, depending on their thickness, cutting thickness (k_q = 0.25,…,0.35) (h_1 > 12(15) cm) and relative height of the layer (h/H > 0.1(0.2)), two technological forms arise [9, 10]:

Note that the sediment is dug out by the hoe along the width of the channel, and the plow is filled at the foot of the slope. At the final stage of digging, a limiting equilibrium is created in the process, and it is considered as the calculated position. After that, the digging process stops and the hoe is brought into the transport position. As in the case of a hoe without a roller, when digging out solid sediment in a roller hoe, the mass of sediment accumulated in front of the hoe can be divided into three-character areas Figure 1:
1) For (h_1 > 12(15) cm) and h/H > 0.15 then, sedimentary layer swells up in the hoe and fills it. This situation is found in large channels.

Modern and new designed long reach hydraulic excavators with its supportive bucket cleaning the channels have high technological capabilities [7]. Distinguishing and special function of the new device that, it has symmetrically located two rollers along the length of the wide blade of bucket, to reduce the resistance, affecting the blade during the working process.

2) For (h_1 > 12(15) cm) and h/H > 0.15 when the first part of the layer maintains its integrity. It rises up to the $\varepsilon = 40° - 45°$ angle of the hoe curvature, and then dissipates; a new sediment flow is formed, swells and rises above the previous one. This process continues until the hoe is filled, and the length of the corresponding total assembly (prism) increases significantly.

The natural slope angle of the sediment accumulation (k_q<0.3), which has turned into a solid paste is 25-34°.

2. PROBLEM STATEMENT

In the second case, the sediment layer's resistance to drilling.

$$W = P + W_p + W_{qb} \tag{1}$$

Hoe's resistance to pushing

$$W_1 = P + W_p + W_{qb} + W_d \tag{2}$$

where, W_{qh} is the resistance of the sedimentary layer swelling and filling the hoe. When the accumulation (prism) increases and the thickness of the shear layer is h_1<$h_B \sin\alpha$, the shear resistance of the layer (ρ) is reduced to a minimum, and the layer is oared with the sliding surface [11, 12].

Total resistance force

$$W = \tau_k + W_p + W_q + W_a + W_i \tag{3}$$

Hoe's tensile strength

$$W_T = \tau_k + W_p + W_q + W_a + W_d + W_i \tag{4}$$

where, τ_k is the sedimentary layer's resistance to oar W_p is the resistance of the sediment layer (prism) to transmission; and

W_q is the rise and spread resistance of the layer through the collection surface (in the balanced state);

W_a is the sediment flow resistance at an angle;

W_d is the movement resistance of rollers;

W_i is inertial resistance.

Depending on the nature of the interaction of the sediment with the working tool and the technological parameters, the sedimentary layer is cut or shoveled. When studying the adhesive properties of soils and sediments, their adhesion to working tools was also studied to a certain extent.

It is known that when cutting clay soils under high pressure, for example, in deep faces, a hardened core is formed in front of the cutting tool, which firmly attaches the mass of soil to the tool, depending on the properties of the clay. Obviously, its tear or slip resistance must be very large. On the other hand, precipitation occurs weakly, since it occurs in water conditions.

For the above reasons, the adhesion of clay soils to working tools, as well as to other materials, was studied under normal stress conditions (N≥15 N/cm^2). It was found that at the humidity of the average clay soil $\omega = 20,\ldots,25\%$, the coefficient of its adhesion to the steel plate is $0.7,\ldots,1.2$ [16]. The experiments were carried out in the laboratory, and their results were associated with the stamp. So, in a stamp with an area of 10 sm^2, wet soil is compacted with a force of 1 N/cm^2, dough is made from it and the strength of its adhesion to the surface in the normal direction is measured.

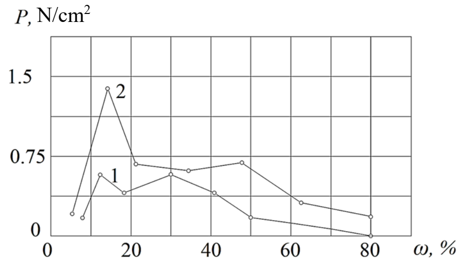

Figure 2. Graph of the dependence of soil viscosity on humidity: 1: soil to light clay; 2: soil to medium clay

It can be seen from the diagram Figure 2 that the viscosity index of light clay soil is relatively close to the viscosity of the sediment. As in the case of soils, in deposits $K_q \le 0.28(0.3)$, while the normal force (cutting resistance) acting on the blade is directly proportional to the thickness of the cutting layer. Therefore, and since the process takes place in an aqueous medium, the components of the total resistance force without taking into account viscosity are calculated in the following sequence.

Depending on the nature of the interaction between the sediment and the working tool and the technological parameters, the sediment layer is cut or oared. The components of the total resistance force are calculated by the following formulas. The layer's resistance to oar

$$\tau_k = (C_n h_l + \sigma_c \cdot tg\varphi_B \cdot l_p)B \tag{5}$$

where, C_n is an indicator of internal adhesive adhesion of sediments;

σ_c is normal stress caused by the swollen sediment layer on the sliding surface;

B is the width of the hoe;

φ_B is the adhesive friction angle between the sediment and the sliding surface.

For $\omega < 35(40)\%$, $\alpha < m \cdot p_c$, and $h_l > m \cdot l_b .\sin\alpha$, when the sediment layer is cut at an angle and resistance force [2]

$$P_c = K_c \cdot B \cdot h_l \cdot K_\varphi \tag{6}$$

where, K_c is the unit shear resistance coefficient of the sediment layer, kN/m ^{2};

K_φ is adhesion coefficient of sediments;

l_p is the length of the layer deformed by the influence of the angle and approximately equals to the length of prism.

When oared, (Δh) sediments flow under pressure from the pore left under the angle. Its resistance

$$W_a = (C_n + \sigma_p \cdot \mathrm{tg}\,\varphi_0)B \cdot \Delta h, \ \mathrm{tg}\,\varphi = \frac{\mathrm{tg}\,\varphi_m + \mathrm{tg}\,\varphi_b}{2} \tag{7}$$

where, σ_p is the normal stress caused by the prism in front of the sub-angled window;

$\mathrm{tg}\,\varphi_\alpha$ is the coefficient of sliding surface friction of metal $\mathrm{tg}\,\varphi_m$ with segments.

Resistance to movement of rollers [17]

$$\tau_d = N_d \cdot K_f = n \cdot N_k \cdot K_{qb} \cdot K_d \cdot K_f \tag{8}$$

where, N_p is the normal force per one roller, n is the number of rollers, n=2–4.

K_{qb} is the coefficient of unevenness of the load falling on the rollers, K_{qb}=1.0, …, 1.1;

K_d shock coefficient is taken into account when there are spills in concrete steps and seams, K_d=1.0, …, 1.2.
N_d is regulated by hydraulic cylinders that raise the working body.

3. PROBLEM SOLUTION

A part of the sediments is transported in a hoe (W_c), the second part is dragged (W_s).

$$W_p = W_k + W_c = a_1 H^2 B \gamma_c f_k + a_2 H^2 B \gamma_c \operatorname{tg}\varphi_b = = H^2 B \gamma_c \left(a_1 f_k + a_2 \operatorname{tg}\varphi_b\right) \tag{9}$$

As the state of the hoe changes during the work process, the volume of the sediment prism, the nature of its transport and, accordingly, the resistance force change. This change can be adjusted with the surface pressure indicator (A_{pr}) of the sediment collection (prism). The volume of sediments transported in the hoe increases by, ΔQ the dragged volume decreases on the contrary by ΔQ.

$$\Delta Q = H^2 \cdot \sin\left(90° - \varepsilon\right) B$$

$$W_p = H^2 B \gamma_c \{[a_1 f_k + \sin(90° - \varepsilon)] + [a_2 \operatorname{tg}\varphi_b - \sin(90° - \varepsilon)]\} \times \times \frac{\sin(\varepsilon - \rho_c)}{\sin 2\varepsilon \cos \rho_c}\left[1 + \sin\rho_c \ \sin\left(\varepsilon - \rho_c\right)\right] \tag{10}$$

where, ρ_c is the angle of internal friction of the sediments with adhesive. The resistance of the sedimentary layer to rise on the prism.

$$W_q = h_l \frac{H \cdot K_a}{\sin\beta} B \cdot \gamma_c \cdot \operatorname{tg}\varphi_c \cdot K_y \tag{11}$$

where, K_a is the dispersion coefficient of the rising layer, $K_a = 1.1, \ ..., \ 1.15$.

Inertial resistance reflects the effect of the entire pushed prism mass when observed in the roller zone, and the mass (Q_1) of the shear layer when encountered in the shear zone.

$$W_i = aBH^2 \cdot \gamma_c \frac{1}{g} \cdot \frac{d\upsilon}{dt}$$

$$\alpha = 0.6, \ \ldots, \ 0.75 \tag{12}$$

$$\frac{d\upsilon}{dt} \approx 0.05, \ \ldots, \ 0.10 \text{ m}$$

It should be noted that with the help of similarity theory, the possibility of calculating the energy capacity of sediments using drilling theory was revealed, depending on the state in which a close relationship between sediment drilling and soil drilling was sought. It was found that some sedimentation processes, in particular sediment shoveling can be controlled by the regularity of "statics of cast soils".

By a given resistance force, it is possible to determine the force spent on drilling and lifting the sediment with a hoe. In this case, the design power should be less than the engine power. By a given resistance force, it is possible to determine the force spent on drilling and lifting the sediment with a hoe. In this case, the design power should be less than the engine power [18],

$$N_1 + N_2 \le N_{eng} \tag{13}$$

where, N_1 is the power spent on overcoming the resistance force, kW;
N_2 is the power spent on lifting the hoe, kW.

$$N_1 = \frac{W_T \upsilon_t}{\eta_g} \tag{14}$$

$$N_2 = \frac{P_q \upsilon_q}{\eta_q} \tag{15}$$

Thus, if we write Equations (14) and (15) in (13), we get

$$N_{eng} \ge N_1 + N_2 = \frac{W_T \upsilon_t}{\eta_g} + \frac{P_q \upsilon_q}{\eta_q} \tag{16}$$

where, υ_t is speed of movement of working body, m/sec,
υ_q is the lifting speed of the working body, m/sec,
η_g is the efficiency factor of transmission and carrier
η_q is the efficiency factor of hydraulic system equipment
W_T is the rolling resistance of the hoe (in the case of a roller), N
P_q is resistance of sediment to shear and rise N

The results of the report differ by ±6% from the in-kind indicators (B = 1.5 m, B = 1.5 m^3) of the channel cleaner assembled on the excavator EO-3322a.

4. CONCLUSIONS

Channel sedimentation and siltation occur in all areas of the flood plain when the current velocity is less than about 0.7 m/s. Sedimentation processes are independent of the channel type, and clogging speeds up the process. Torrential rains and flood waters discharge sand particles together with fine particles into channels in flooded areas. Various wastes are discharged from additional residential areas. As a result, it becomes very difficult to clean the channels qualitatively.

While analyzing of current taxologies and cleaning methods of concrete lining and soil channels, it was determined certain advantages and disadvantages of each method. According to the global practices, the necessity of choosing an effective method of cleaning and improving the technology with its application is justified by choosing the design of an effective working body that allows for high-quality cleaning of irrigation channels (B_k = 2,…,8 m) from sediments and plants.

During the drilling process in concrete-lined channels, as the sediment accumulates inside the hoe, resistances arise from various effects, from the transport of the sediment layer (prism) between the sediment and the working body, from the rising and spreading of the layer on the collecting surface, from the flow of the sediment under the blade, from the movement of the rollers, and from inertia. From the research conducted in laboratory conditions, it was found that the low height of the blade causes the formation of a prism of the layer of sediment in front of the hoe is oared, so the height of the blade is increased. The new working body is equipped with a hoe, a flat blade and two rollers.

The conditions of the sedimentary mass in the covered and uncovered are described in nature; its thickness is determined depending on the time of accumulation of mass, thickness, water conditions, clogging and the regime of the channel. To create the recess, devices with wire mesh type sensors attached to the surface of the layer (bushings) and to heavy-duty cylinders were used, as well as with membrane sensors that contribute to the destruction of holes, and with the help of oscillators of complex strain gauges.

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