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Dredging technology of placer deposits in the far north

Uzak kuzeydeki plaser tabakalarının tarama teknolojisi

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A B S T R A C T

The authors consider the problem of reducing the dredge performance when operating at subzero air temperatures. This problem is particularly relevant for deposits located in the Far North, where the dredging season is limited by climatic conditions. During the period of subzero air temperatures dredge performance decreases significantly due to the icing of dredge structure. In consequence, dredging operations are terminated until the occurrence of favorable conditions for work. In this regard, the authors propose a method for isolating the open-pit mine with a hangar made of contemporary construction materials. Cellular polycarbonate, which has several advantages, was chosen as the most promising material for insulating dredging works. The article offers the technical and technological solutions for the proposed method of extending the dredging season. The costs of a dredge hangar for dredges of different sizes and the annual cost of its movement are calculated. A method has been developed for determining the optimal maneuvering angle of the dredge and the width of the single face, whose values depend on the type of dredge and the gold content in the sand. The areas of dredge hangars are determined by the graphical-analytic method. The article presents an example of the air temperature dynamics in a dredge hangar during the year, as well as determines the duration of the mining season.

Keywords: *Placer deposit, Placer gold, Dredge, Mining season, Dredging hangar, Winter season, Far North, Productivity*

Introduction

Currently, one of the most promising areas in the mining industry of most countries is the extraction of gold, whose significant reserves are contained in placer deposits. The occurrence conditions of such deposits make it possible to effectively apply relatively simple technologies. The dredging method has the highest technical and economic indicators in the development of placer mineral deposits, which has several advantages, such as high productivity, minimum cost, and the possibility of implementing in complex hydrogeological conditions (Zhuravlev, 2018; Yershov, 2010; Belov, 2011; Talgamer and Chemezov, 2012; Garnett, 2015; Zhang et al., 2019; Ryzhov, 2020; Kashirtseva, 2019; Rafkatovich and Mironova, 2018).

A significant part of the world's placer reserves is located in northern latitudes with severe climatic conditions. At that, the ambient air temperature is one of the main factors affecting the duration of the mining season during the dredge development of deposits. At subzero air temperatures water freezes in the section, as well as the rock freezes on the scoops and the dredge scooping frame, which leads to a decrease in daily productivity (Rafkatovich and Mironova, 2018; Kostromin, Yurgenson and Pozlutko, 2007; Nurok, 1970; Shorokhov, 1973). It is possible to increase the dredging productivity in the Far North conditions by using floating foams, ice-cutting machines, using the heat of deep waters of reservoirs, water circulation in the bottom water area, changing the chemical composition of water, and others. But

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practice shows that all of the above methods are not widely used due to high economic and energy costs, labor intensity, and environmental damage.

The most promising method of extending the dredging season is a proposed method of isolating the dredge section against the effects of subzero temperatures with a hangar made of contemporary construction materials (Shorokhov, 1973; Kislyakov and Nafikov, 2016; Kislyakov et al., 2017; 2018) (Figure 1). One of these materials is cellular polycarbonate having several advantages. At that, the frame of the hangar should be designed using metal structures to strengthen its structure.

The hangar surface should be sprayed with transparent hydrophobic compositions that have the cryophobic property, i.e. the ability to prevent ice and snow from freezing to them.

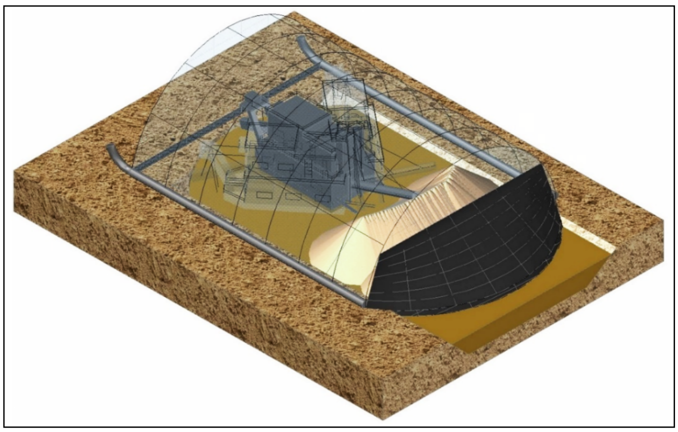

Figure 1. *Schematic diagram of isolating the dredge section by the hangar during the field development throughout subzero temperatures*

The hangar is mounted on a metal sled to allow it to be transported using mining equipment, such as a bulldozer. The lower part of the hangar on the side of the dredge stacker must be made in the form of folding rubber sheets. In the course of moving the canvas affected by the weight will lean on the dumps and move along them, excluding heat losses from the hangar. The height of the canvases attachment is determined based on the maximum height of the dumps under certain conditions and is adjusted during the entire period using the hangar. The front part of the hangar is also equipped with rubber sheets, whose height should be equal to the height of the sled. Thus, the safe operation of the hangar during its transportation is provided.

To allow workers to enter the hangar, as well as for the delivery of goods to the dredge, the hangar is equipped with a door, which is located in its front part at the location of the dredge ramp. All the necessary materials (especially large-sized and heavy enough) are brought to the dredge whenever appropriate before the installation of the hangar structure. After isolation, the passage of transport inside the hangar is excluded, while the delivery of materials should be carried out manually. At that, the distance to the dredge will be only 5-10 meters depending on particular conditions. One can use a crane mounted on the front mast of the dredge.

The air temperature inside the hangar allows maintaining the section in a non-freezing state. If it is necessary to clean the section from ice and sludge, one can use winches installed on the dredge with a loading device in the form of a grid. One can also use a crane with a loop as an ice grab, located on the front mast. The ice can be removed with the dredge itself, namely, using scoops. The ice is removed through the barrel and stacker into the dumps. For small volumes of ice and sludge, one can use manual cleaning.

The turns of the pile dredgers are carried out using side ropes that are passed through the shore rollers, which reduces their wear when moving on the placer surface, and also reduces the load on the winch engine. In turn, the rollers are attached to the shore through the drawbar. According to the proposed technology, shore rollers should be installed behind the hangar perimeter close to it, then the exposed areas in the hangar structure are minimized. It is necessary to fix the roller on two or three braces, which allows preventing its movement when turning the dredge.

The excavating of rocks in the vertical plane can be done either layer-by-layer or working of the face from the bottom or the intermediate horizon by sub-working the ledge and then excavating the collapsed rock. In the latter case, the rock slide can affect the stability of the hangar, so it is necessary to use only a layer-by-layer excavation. At that, it provides the best conditions and performance of the dredge.

The proposed technology provides that in the summer season, mining operations are carried out according to any development system. At the same time, the landfills intended for winter mining are opened. Next, the prepared area is protected from freezing. To date, there are many ways of such protecting, for example, laying thermal-insulating coverings, flooding of prepared sites, and others. The most economical type is autumn loosening of the soil.

Also during this period, a sump tank should be prepared next to the site intended for winter mining. The sump serves as an additional source of water supply to the dredge section during the period of stable subzero ambient air temperatures. When calculating the sump volume, one should be guided by the necessary inflow of water into the dredge section, which is about 50-200 l/s for different dredge models. It is also recommended to take into account the thickness of the ice cover in winter.

By the time of the onset of late autumn, the dredge should be approached the prepared area. During this period, the installation of the hangar is carried out. For the rational use of working time, it is recommended to combine repair works on the dredge with the installation of the hangar. The average duration of major repairs on dredges is 30-60 days. To reduce it, it is recommended to carry out work in three shifts, which will allow completing the repair in 10 days. After the completion of the auxiliary work, the prepared area is worked out while mining and processing operations, as well as dump formation in the winter period are carried out inside the hangar.

When applying the proposed technology, it is recommended to plan the works so that one excavation site provides production throughout the winter, which will eliminate the reversals of the dredge and hangar. In this case, the scheme of operation is simplified, while the cost of dredging and preparatory work will be significantly reduced. Therefore, with the proposed technology, it is not advisable to use longitudinal and adjacent development systems. In cases where a turn of the dredge and the hangar is intended for working out the face in mutually opposite directions, it is recommended that the dump formation be carried out on the outer side of the section, which facilitates the installation of the hangar after the turn of the dredge.

1. Research methods

To determine the parameters of the hangar, it is necessary to determine the maneuvering angle and the width of the single dredge face. Consider the possibility of calculating these parameters using the following known formulas:

$$\beta = 18{,}7 \cdot \sqrt[3]{10^6 \cdot \frac{\upsilon_{lm}}{k_c \cdot R} \cdot (t_1 + k_c \cdot t_2)}, \text{ degrees} \qquad (1)$$

$$B = 2 \cdot R \cdot sin\frac{\beta}{2}, \text{m} \tag{2}$$

where is the lateral movement speed of the dredge along the face, m/s; k_c is the number of removed rock layers during the layer-by-layer mining of one face; R is the radius of dredge scooping, m; t_1 is the time required for one step, h; t_2 is the downtime of the dredge in the corners of the face when moving to the excavation of the underlying rock layer, h (Leshkov, 1985).

However, when using the proposed technology, the above formulas do not consider the cost of the hangar, its change at different angles of maneuvering of the dredge, and the gold content in the sand. Therefore, the optimal width of a single dredge face will be carried out using the method presented below.

Let's consider how the dredge performance will change when using the proposed technology:

$$Q_ч = \frac{60 \cdot n \cdot E}{K_p} \cdot K_s, \text{m}^3/\text{h} \tag{3}$$

where n is the speed of the scooping chain, scoops/min; K_p is the swell factor of rocks; K_s is the average fill factor of scoops with rock.

The fill factor of scoops with rock depends more on the angle of the dredge maneuvering. Thus, at an angle of 60 degrees, the fill factor is 0.95, while at an angle of 140 degrees, it decreases to 0.77.

The average annual dredge performance is determined by the equation:

$$Q_{year} = 24 \cdot Q_s \cdot K_u \cdot T, \text{m}^3/\text{year} \tag{4}$$

where K_u is the labor utilization rate.

Using the formulas presented above, one can calculate the performance of dredges of different standard sizes at the traditional technology of field development and the proposed one.

Knowing the annual performance, it is possible to determine the profit of the enterprise (part of the results is shown graphically below). The calculations will require knowing the gold content in the sands and the cost of mining operations.

When applying the proposed technology, it is also necessary to take into account the cost of the hangar and the annual cost of its movement (Figures 2, 3). The cost of the hangar includes the cost of polycarbonate, metal pipes, sleds, and installation of the structure.

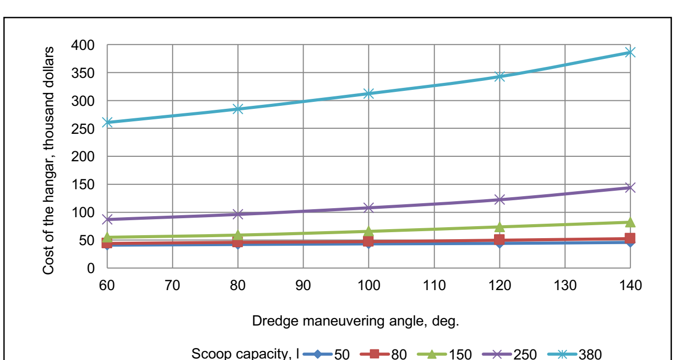

Figure 2. Cost of the hangar depending on the type of dredge and maneuvering angle

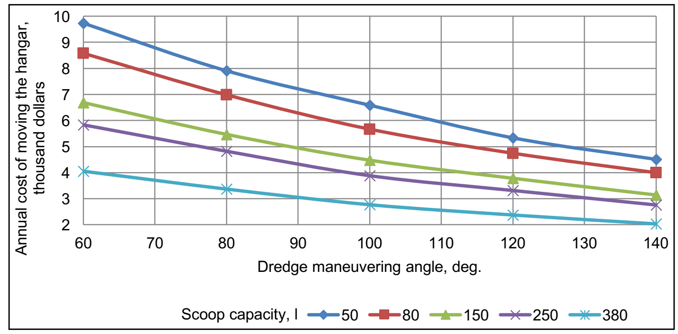

Figure 3. Annual costs for moving the hangar for different dredge maneuvering angles

2. Results

Next, the difference in net profit at traditional and proposed technology is determined for different size dredges, different maneuvering angles, and gold content in the sand. As an example, Figure 4 shows the increase in profit when operating a 250-liter dredge employing the proposed technology. Here horizontal lines show the cost of the hangar. The presented results are obtained at a gold content in the sand equal to 0.1 g/m³.

While plotting the graphs, equations of the form C=m·T were obtained, where C is the profit in million rubles obtained when using the proposed technology, m is the coefficient depending on the type of dredge, and the maneuvering angle; T is the payback period in years.

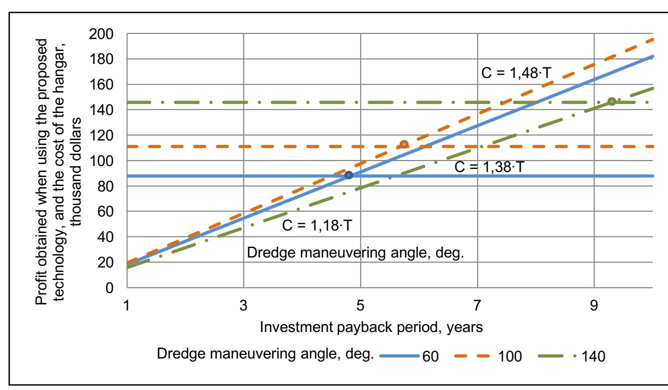

Figure 4. Profit and cost of a hangar for a 250-liter dredge at gold content in the sand equal to 0.1 g/m³

Knowing the profit and the coefficient m, the payback period of the investment was found for different dredge maneuvering angles. Based on the obtained values, a curve is constructed whose equation most accurately describes the location of the values on the graph (Figure 5). The point corresponding to the shortest payback period is the most advantageous, and the corresponding dredge maneuvering angle is the most optimal.

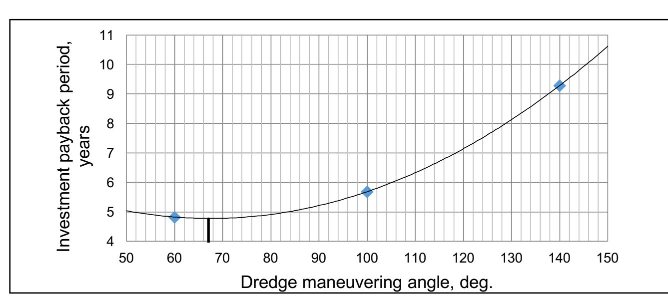

Figure 5. Dependence of the payback period for a 250-liter dredge on the maneuvering angle at a gold content in the sand of 0.1 g/m³

Thus, when using the proposed technology with a 250-liter dredge at a gold content of 0.1 g/m3, the optimal dredging angle is 67 degrees. The optimal dredging angles for other mining conditions are shown graphically in Figure 6.

Next, the optimal width of a single front bank is determined according to the known dependence (2). The calculated data, as well as the resulting equations, are presented in Figure 7.

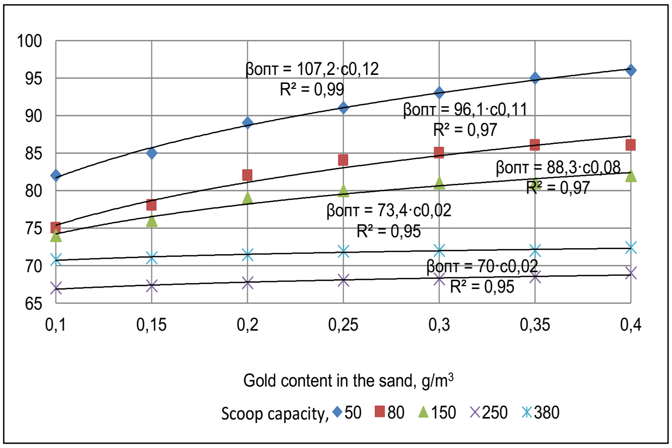

Figure 6. Optimal maneuvering angles depending on the dredge type and the gold content in the sand

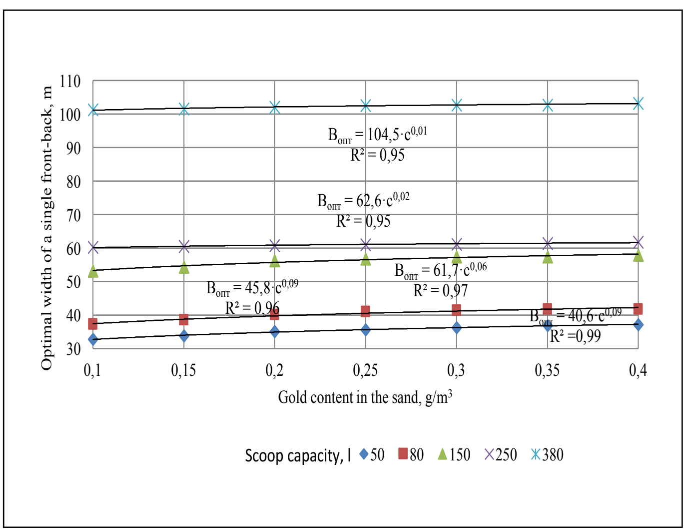

Figure 7. Optimal width of a single front back depending on the dredge type and the gold content in the sand

When using the technology to isolate the dredge section from the effects of subzero temperatures, it is necessary to solve the following problem. On the one hand, it is necessary to ensure the safe maneuvering of the dredge in the hangar, while on the other hand, to create a hangar with the minimum possible size to reduce the capital costs of its construction..

The hangar area can be determined based on the graph analytic method and using the known optimal width of a single front bank. According to the calculated values of the face width, one can build hangars for the dredging of different models employing the AutoCAD software. At that, the safe gap on each side equal to 0.5 m should be taken into account, assuming a one-step movement of the dredge within the hangar, which is an economically feasible option.

The results are shown in Figure 8.

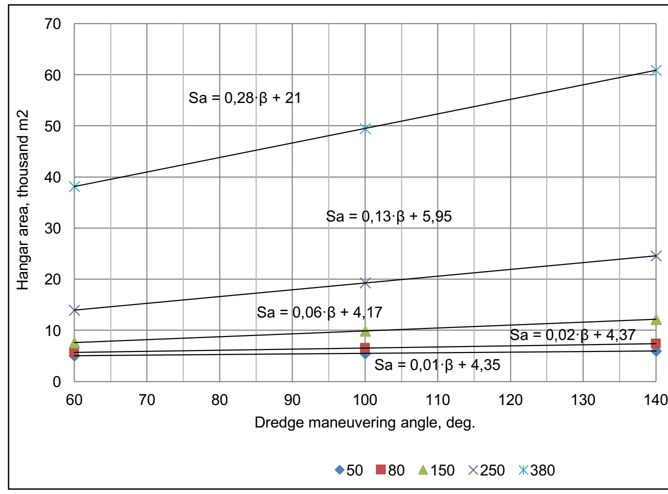

Figure 8. Hangar area for different types of dredgers at different maneuvering angles

3. Discussion

Below is considered the change in the annual performance of dredging when applying the proposed technology for dredge isolating. As an example, a conditional field located in the Far North is considered whose development is carried out using a 250-liter dredge. The insulating material for the hangar is 10 mm thick polycarbonate with a light transmission coefficient of 0.75.

Figure 9 shows the calculated data of the annual air temperature dynamics in the dredge hangar. At that, it should be noted that the installation of the hangar is recommended in the fall when the ambient air temperature is below the water temperature in the dredge open cast. This allows using the heat released from the open cast water in the dredge hangar with maximum efficiency. Thus, in the area under consideration, the installation of the hangar must be carried out on September 15.

The hangar must be dismantled when a stable above-zero ambient temperature occurs, or when it exceeds the air temperature inside the dredge hangar. In the current case, the date of the dismantling of the hangar is April 24.

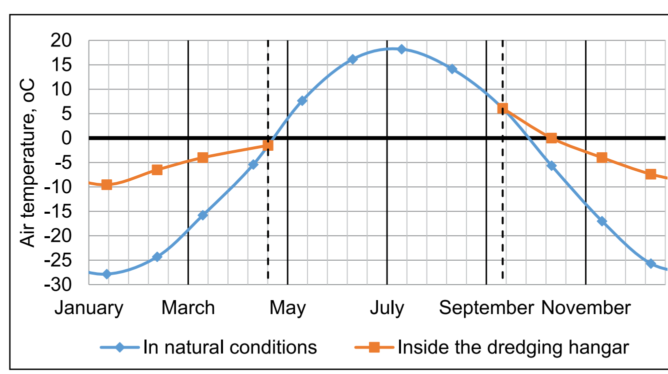

Figure 9. Example of annual air temperature dynamics

Next, the change in the duration of the dredging season when using the proposed technology is estimated. In all cases, the dredging season is limited to the period when the daily performance of the dredge is greater than the minimum allowable performance. The conducted calculations have shown that when the proposed technology is applied at the considered conditional field, the duration of the dredge season increases by 130 days (Figure 10).

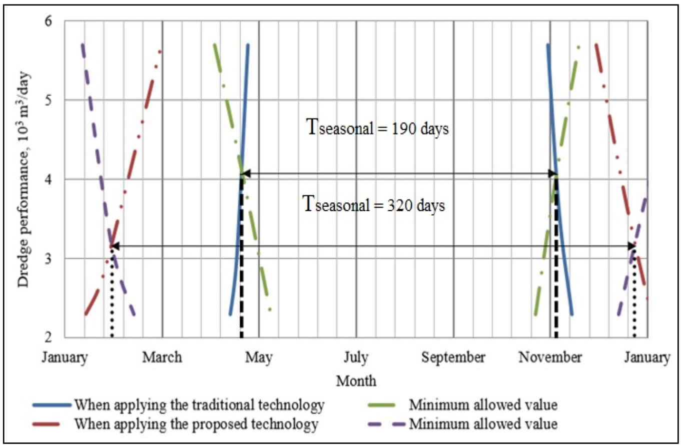

***Figure 10.** Example of determining the rational duration of the dredging season*

Conclusion

Similar studies were carried out for dredgers of different models employed for the development of deposits in the region of 50-70 degrees north latitude. The conducted calculations revealed that the duration of the dredging season increased on average by 100-150 days. In all cases, the annual dredge performance was also significantly increased, which allowed recouping the costs of the hangar and other needs of the enterprise.

For example, when implementing the proposed technology in a field located in the region of 60 degrees north latitude and employing a 250-liter dredge, the total annual economic effect was about 130 thousand dollars.

During the survey, it was also revealed that this method of extending the dredging season in comparison with others has several advantages, such as the possibility of uninterrupted operation at stable subzero temperatures, as well as low cost, and no need for annual capital investments to extend the dredging season, as well as ease of operation.

It should be noted that the isolation of mine workings against the effects of subzero temperatures is possible not only by employing the dredging method of mining but also by using other methods of developing placer deposits characterized by a high degree of the water content of the deposit. Thus, today, the presented technology is one of the most promising areas in the mining industry.

Acknowledgments

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