TEKA. COMMISSION OF MOTORIZATION AND ENERGETICS IN AGRICULTURE – 2014, Vol. 14, No. 4, 169–174

Working of Deep-Water Minerals with Sectored Way

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Received December 09.2014; accepted December 19.2014

Summary. The article presents the problems of obtaining the bottom minerals from the depth of water. The sectored way of working mine is suggested and schemes of movement of the bottom mining are proposed. The calculations are done of movement trajectory of the carriage and length of the hose-cable of the mining machine, taking into account the turn inside and outside the sector.
Key words: deep-water minerals, sectored way, movement trajectory, hose-cable, concretions.

INTRODUCTION

The geological investigations performed in the central areas of oceans during the last decades, allowed to made it possible to investigate the promising for industrial developments areas of poly-metal ore accumulations – concretions – primarily in the region of Clarion-Clipperton on the Pacific ocean [2, 12, 13]. On the regional stage of the geological survey the deposits with overall density of concretions occurrence are identified (up to 10...20 kg/м²), that contain the industrial concentration of manganese, nickel, copper and cobalt [7, 18, 19].

At the same way the technology and technical ways needed for the survey and experimental testing stages of works were developed: collection of concretions and lift to watercraft, pre-processing, storage and handling of the extracted mass to the ore-transporting ship [1, 3, 4, 11, 16].

The conditions of concretions occurrence are complex and unique – it is the depth of 4000...6000 м, low carrying capacity of sediments, big quantity of rocky exits and cavities, variable configuration of sedimentations. The above-specified factors significantly affected the operation of the survey, pilot-testing machines and machinery at the bottom [9, 14, 17]. In such conditions it is reasonable to perform the exploitation works using the fixed or inactive mountain reconnaissance complexes, that include the elevation system that interacts with base bottom module of collection aggregate and fast moving gathering working parts.

The latter are connected to base unit hose cable which provides transportation of the extracted rock mass and energy supply to drive the carriage of the gathering working body [5, 6, 10, 15].

PURPOSE OF THE ARTICLE

The research aimed at the grounding of the possibility of the technological scheme of clearing excavation by sector ways with any predetermined or regulated angle of disclosure of sector. At that, two options of carriage trajectories were offered – with a turn inside the sector or beyond its contours (Fig. 1, 2).

RESEARCH AND CALCULATIONS

The carriage can maneuver at some distance from base module, the maximum radius depends on the length of hose-cable that is reeled from the coil. To determine the amount of time needed for the processing, it is required to identify the area of sector and the length of the way travelled by the carriage, whereas for finding the volume of extraction – the amount of costs on the unprocessed areas of the sector.

During the work of carriage with turn inside the sector contours on each operation cycle of the part of circle with width B inside the sector with angle α is processed. At the end of the strip the carriage is turned 180°, moreover the hose-cable is reeled to the length B that equals the width of carriage and the next operation cycle (see Fig. 1).

The initial data for calculation: α – the angle of turn of sector; B – width of carriage: L_m – length of hose-cable or maximum radius, passed by the carriage; L_0 – radius of the base module of collecting aggregate. Needed parameters:

K – number of operation cycles; R_0 – minimal radius, starting from which the carriage maneuver is possible; *S* – processed (developed) area; *S** – full area of the sector; *E* – percentage of the developed area; *L* – way, passed by the carriage; *D* – specific area, i.e. the area, reduced to the unit of way, passed by the carriage.

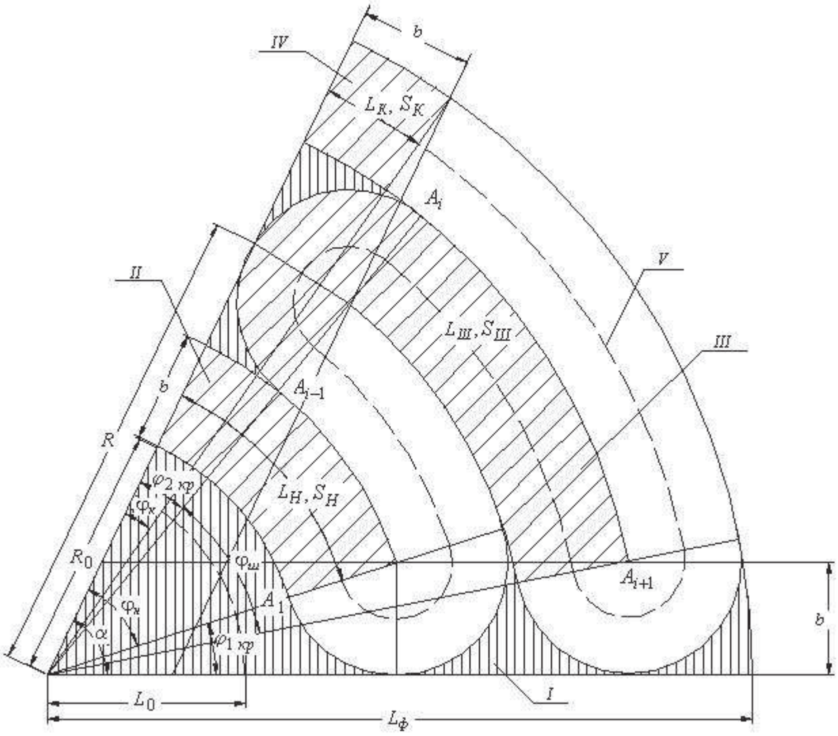

Fig. 1. Calculated scheme of carriage motion trajectory with turns into a sector:
I –not processed areas; *II* - *IV* – processed zones, from them *II* – in the first measure, *III* – on intermediate measures, *IV* – on the last measure; *V* –carriage motion trajectory

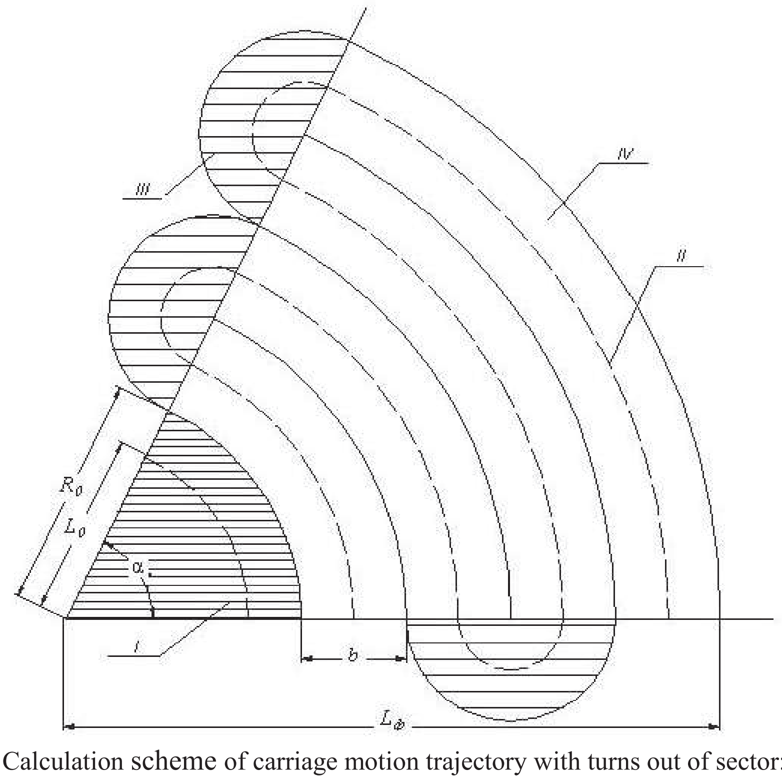

Fig. 2. Calculation scheme of carriage motion trajectory with turns out of sector:
I – not processed space; *II* –carriage motion trajectory; *III* – superfluous areas; *IV* – processed areas

Full area of sector:

$$S^* = \frac{1}{2}(\alpha L_m^2)\,. \quad (1)$$

Number of operation cycles of carriage:

$$K' = (L_m - L_0)/B\,. \quad (2)$$

Minimal radius of carriage turn:

$$R_0' = L_m - KB\,. \quad (3)$$

For the full turn of carriage inside the sector the following conditions are required:

$$\varphi_{1\,cr} + \varphi_{2\,cr} \le \alpha\,, \quad (4)$$

where:

$$\varphi_{1\,cr} = \arcsin B/(R_0 + B)\,, \quad (5)$$

$$\varphi_{2\,cr} = \arcsin B/(R_0 + 2BE)\,. \quad (6)$$

At that $R_0 = R_0' + B$ is used so that to satisfy the condition (4), in this case $K = K' - \xi$, where ξ – safety factor.

Note, that with $K' = 0$ processing is not possible, and with $K' = 1$ only one operation cycle is processed. In the latter case, K is considered equal K', and $R_0 = R_0'$.

In the first operation cycle the carriage is moved from position A_0 to position A_1;
Hose-cable is turned (rotated) at the angle:

$$\varphi_{in} = \alpha - \arcsin B/(R_0 + B)\,. \quad (7)$$

Center of carriage moves the way:

$$L_{in} = (R_0 + B/2)\varphi_{in}\,, \quad (8)$$

processed (developed) area:

$$S_{in} = \frac{1}{2}\left[(R_0 + B)^2 - R_0^2\right]\varphi_{in}\,. \quad (9)$$

At each interim operation cycle the carriage rotates 180° from point A_{i+1} to A, and the length of hose-cable increases by width of the carriage B; then the carriage moves from point A_1 to point A_{i+1}, in the result of which the hose-cable rotates at the angle:

$$\varphi_h = \alpha - \arcsin\frac{B}{R} - \arcsin\frac{B}{B+R}\,, \quad (10)$$

where: R – distance from the carriage to the point of mantling of hose-cable to base module of collecting aggregate.

On each operation cycle the center of carriage passes the way:

$$L_h = \pi B/2 + (R_0 + B/2)\,\varphi_h\,. \quad (11)$$

The processed area makes up:

$$S_h = \frac{1}{2\pi}B^2 + \frac{1}{2}\left[(R + BE^2 - R^2\right]\varphi_h\,. \quad (12)$$

At the last step of the operation cycle after the processing of the land, the area of which is determined by Eq. (10) – (12), the hose-cable rotates at the angle:

$$\varphi_c = \arcsin\frac{B}{L_m}\,. \quad (13)$$

At that the carriage passes the way:

$$L_c = (L_m + B/2)\,\varphi_c\,. \quad (14)$$

And the land is processed:

$$S_c = \frac{1}{2}\left[L_m^2 - (L_m - B)^2\right]\varphi_{\hat{e}}\,. \quad (15)$$

The total way and area (L i S) one calculates as sum of corresponding sizes of areas on the initial, all the intermediate ones and the final operation cycle.

The percentage of the processed area:

$$E = (S/S^*)100\,, \quad (16)$$

specific area:

$$D = S / L. \quad (17)$$

With work of carriage with turn outside the contours of sector with angle α on each operation cycle the carriage processes the part of the circle with width B (see Fig. 2). At that the part of the hose-cable that equals the width of the carriage operation cycle is reeled from the coil placed on the base module of collecting carriage.

When you save the similar to the above considered variant output data, you need to add to the desired (searched) parameters the following: S_1 – area, processed by the carriage outside the contours of the sectors (extra area); E – percentage of extra area; L_1 – extra way and E_1 – percentage of extra way.

In this case the full area of sector, the number of operation cycles and minimal radius are accordingly determined with Eq. (1) – (3).

Useful area, processed with aggregate:

$$S = \frac{1}{2\alpha}(L_m^2 - R_0^2). \quad (18)$$

Extra space at that is:

$$S_1 = (K-1)\frac{1}{2\pi}B^2. \quad (19)$$

Since processing of K operation cycles one needs to perform $(K – 1)$ of turns. The percentage of processed area in the sector is determined with expression (16).

The percentage of extra areas processed by the carriage (%):

$$E_1 = \frac{S_1}{S + S_1}100. \quad (20)$$

The way passed by the carriage consists of segments of way with useful processing and ways passed for rotation. Useful way is calculated with the formula:

$$L = (R_0 + B/2)\alpha + (R_0 + B/2 + B)\alpha + \\ ...[R_0 + B/2 + (K-1)B]\alpha = \\ = \frac{1}{2\alpha}K(2R_0 + KB). \quad (21)$$

Extra way, or way passed for the turn:

$$L_1 = (K-1)\pi\frac{B}{2}. \quad (22)$$

Extra way, passed by carriage (%):

$$E_L = \frac{L}{L + L_1}100, \quad (23)$$

specific area:

$$D = \frac{S}{L + L_1}. \quad (24)$$

Mathematical model is done for collecting aggregate that processes with sector scheme the ore deposits with complex configuration with big quantity of obstacles on the bottom like rocky exits and cavities, etc. By means of computer program the following values are calculated; K, R_0, S, S^*, S_1, E, E_1, L, L_1, E_L, D for angles α = 45°...315°, width of carriage seizing B = 1,5...6,5 м with length of hose-cable L_m = 100...200 м.

Hand productivity of mining company with 1 million of concretions can obtain minerals with minimal losses by using as part of the collection aggregate of lightweight high-speed carriage, that has to be characterized by coordinating connection with the base module.

CONCLUSIONS

1. In the depth of the open ocean there are big areas with concretions lying on the bottom surface with increased (up to 10...20 kg/м²) density. Mining conditions of these deposits are notably hard due to prominence of landforms and the presence of rocky exits.
2. Due to the necessity of choosing equipment and technology of sewage treatment works, the organization of excavation works with the scheme with sedentary collection unit (base module) and fast moving excavation unit (pickup) is suggested.
3. The determination of parameters of minerals extraction is given basing on the extraction of more than 1 mill of concretions per year with their minimal losses by means of usage of coordinating connection between the pickup and base module with sector scheme.
4. The mathematical model is given and key parameters of sector method of concretions pickup are calculated.

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РАЗРАБОТКА ГЛУБОКОВОДНЫХ ПОЛЕЗНЫХ ИСКОПАЕМЫХ СЕКТОРНЫМ СПОСОБОМ

Аннотация. Показаны проблемы добычи донных полезных ископаемых из большой глубины. Предложен секторный способ разработки месторождения и приведены схемы движения донного добывающего агрегата. Выполнены расчеты траектории движения каретки и длины шлангокабеля добывающей машины с учетом разворота внутри сектора и вне его пределов.

Ключевые слова: глубоководные полезные ископаемые, секторный способ, траектория движения, шлангокабель, конкреции.