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Dependence of pit deepening rate on organization of mining for development of new horizon

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Abstract
Combined technological diagrams of development of deep horizons of iron ore pits under difficult hydrogeological conditions are developed and classified; their technical and economic indices are determined in the paper. The dependence of pit deepening rate on organization of works on development of shoulders and structure of complex cross-loading equipment is established.
Key words: DEVELOPMENT OF HORIZON; TRENCHING TECHNIQUE; DEEPENING RATE

Statement of problem and its connection with scientific and practical tasks.

Maintenance of the specified ore productivity of pit is provided with timely filling and increasing of ore front due to development of the new horizons. In the iron ore open-pits, the maximum deviations from planned volumes of production are connected to works performance in the lower horizons. Dependence of open mining operations on climatic conditions is most brightly shown in a depth zone of a pit, which accumulates underground and storm waters runoff that causes intermittent flooding of a bottom of deep pits. The mining conditions, under which the operation of electric open-pit excavator is impossible, are formed.

Influence of hydrogeological and climatic conditions on mining and development in the deep horizons of open-pits was not reflected in the theory of mining.

The analysis of results of meteorological researches has shown that the whole territory of Ukraine has inherent tendency of annual increase in quantity and intensity of shower precipitation [5]. As a result, some errors in pit deepening rate and its possible productivity on ore may be introduced at a stage of pre-design and design decisions making on deposit development. There is a need for improving of methods of pit deepening rate determination considering hydrogeological and climatic factors and for development of new technological diagrams of trenches building under complicated hydrogeological conditions.

Statement of objective and research problems

Work objective: improving of methods of pits design due to considering of hydrogeological conditions of the opened horizons and structure of complex of cross-loading equipment used in case of driving of entry trench when pit deepening rate determining.

Investigation tasks:

1) To develop and investigate the alternative methods of construction of entry trench with use of pit mechanical and hydraulic excavators.

2) To determine the dependence of economic indicators of trench construction under hydrogeological conditions of the opened horizon and structure of complex of cross-loading equipment.

3) To study dependence of pit deepening rate on the organization of works for development of new horizon.

Analysis of the latest researches and publications

In the papers [1, 2, 6, 7], the analytical principles of determination of possible pit deepening rate are grounded. These dependences are determined for driving of entry trench by the mechanical excavator along the shoulder full height. In practice, the layer-wise diagram assuming a construction on each layer of several temporal sumps is used when opening of the flooded horizons using a front mechanical shovel [5]. In this case, the front mechanical shovel operates by inefficient and unsafe technology with perhaps abnormal flooding of mining equipment arranged at the bottom of trench. In case of the equipment flooding, its further operation is possible only after repairing of excavator electrical part.

Combined technological diagrams with use of various cross-loading equipment, those are front mechanical and reverse hydraulic shovels, have been developed. Depending on procedure of mining operations and sequence of use of various cross-loading equipment, combined diagrams of trenches driving under complex hydrogeological conditions can be divided into diagrams with parallel (simultaneous) and sequential use of various equipment (Figure 1).

Parallel diagrams assume simultaneous operation of various cross-loading equipment. Construction works of trench are organized in such a way that hydraulic backhoe constructs the advanced water water-reducing trench along the final boundary of constructed opening. Then, the front shovel starts developing of the first layer; thus, the hydraulic shovel conducts deepening of a water-reducing trench after formation of area with the parameters allowing operation of the second excavator in the base of layer (Figure 2).

In case of sequential technological diagrams, at first the hydraulic excavator performs operation, then the mechanical shovel starts working. It is obvious that in case of sequential diagrams, minimum necessary amount of works for shoulder dewatering and creation of the conditions favorable for effective and safe operation of the mechanical excavator is equal to the volume of truncated turned pyramid, which height is equal to shoulder height considering sump depth. One edge of pyramid must be presented by a surface with the slope angle providing movement of mining and conveyor equipment used in construction of open pit.

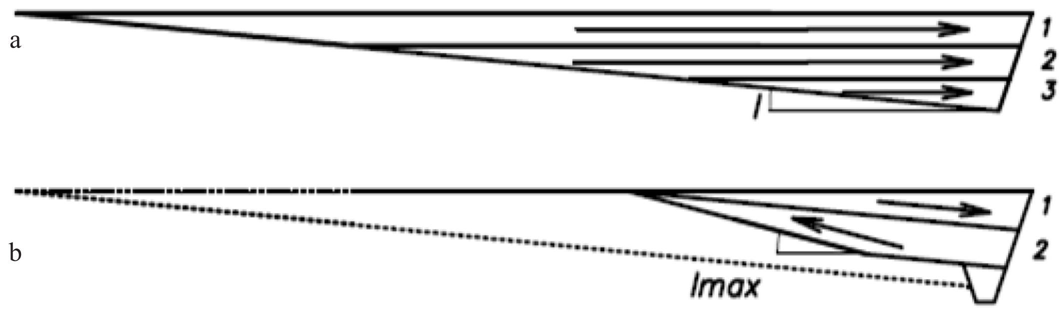

Figure 1. The direction of motion of hydraulic backhoe bottom when operating with parallel (a) and sequential (b) diagrams. 1, 2, 3 –the first, second and third layers of water-reducing trench respectively; final boundary of entry trench is marked by dashed line

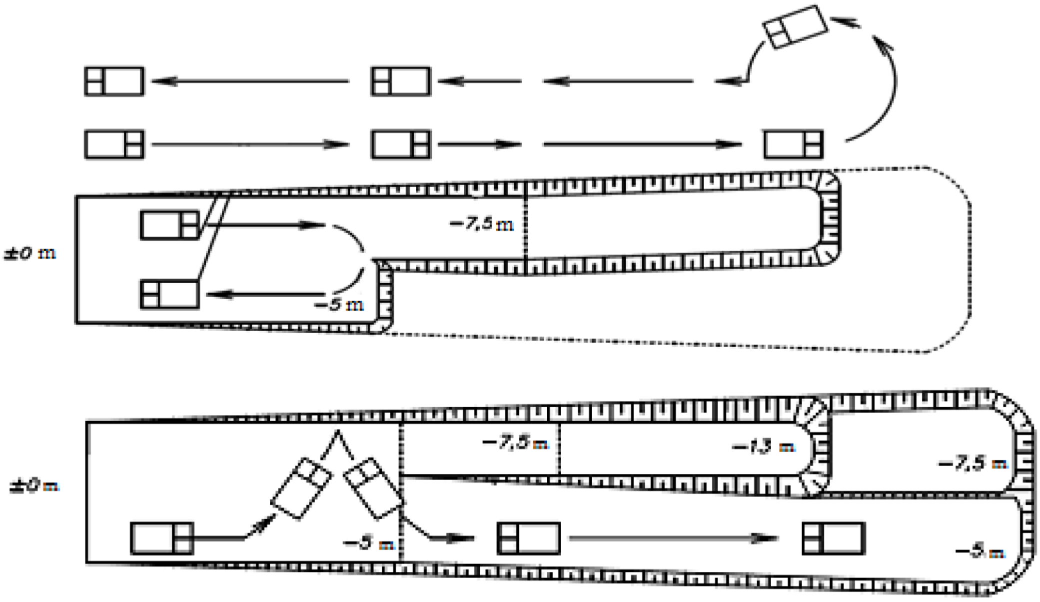

Figure 2. The diagram of a trench driving with parallel use of mechanic and hydraulic excavators (process flow coefficient $К_{p.f.}$=0,51, coefficient of operation area of hydraulic excavator $К_{o.c.}$=1)

Construction of the advancing water-reducing trench is carried out layerwise by inclined layers. Driving of the first layer is performed with transportation of excavator bottom in the direction of depression of bottom of entry trench under construction; and driving of the second and the subsequent layers is performed with undercutting of overlying layers in the opposite direction (Figure 3). For reduction of length and volume of the advanced water-reducing trench, the last layer is driven with the increased slope allowing movement of crawler machines.

In the face part of the constructed entry trench, hydraulic backhoe constructs the inclined advanced water-reducing trench. Along the bottom, the minimum width of the water-reducing trench must be not less than width of the single-band highway considering safety berm. For decrease in the costs of entry trench construction, amount of operations, which are carried out by the backhoe, must be minimum but sufficient for creation of the conditions providing effective operation of mechanical shovel. Against this background, the further deepening of the advanced water-reducing trench must be performed without increase in its length (Figure 3). For implementation of this conditions, the reverse hydraulic excavator carries out undercutting of bottom of the advanced trench by reverse motion in such a way that part of its bottom is cut across the width with the increased slope forming an area for operation of the excavator, and another part is 2-3 m deeper than the first one (Figure 3) [5]. In cross section, the bottom of advanced trench becomes stepped. The lower part of a bottom functions as sump. After shoulder dewatering, the mechanical excavator (Figure 3c) starts working. The main distinction of sequential schemes is that the trench is driven by the front mechanical shovel along the full height of shoulder. It makes technical indicators of excavator operation closer to indicators when driving of unwatered horizon.

For the characteristic of developed schemes of trenches construction, the coefficient of technological scheme is used; it is equal to the ratio of rocks volume excavated by the hydraulic backhoe to the total amount of mining operations on trench construction. So, if value of coefficient of the technological scheme $К_{p.f.}$ is equal to 0.5, it means that in the edge of trench, a half of volume of rocks is excavated by the hydraulic backhoe; if $К_{p.f.}$=0, all volume is developed by a mechanical shovel; if $К_{p.f.}$=1, all volume is developed by a hydraulic shovel [5]. For the characteristic of length of operation area of hydraulic shovel, the coefficient of operation zone of the hydraulic excavator is used; it is equal to the ratio of length of mine opening constructed by the backhoe to the total length of trench. Using the mechanical shovel and reverse hydraulic excavator with ladles capacities of 10m^3 and 15m^3 respectively as an example, technical and economic calculations for the developed combined schemes of construction of entry trenches are conducted. The data from the reference book “Mine and mill equipment costs” were accepted as basic data for economic calculation. Operational costs for trenches driving are given in the diagram according to the developed technological schemes (Figure 4).

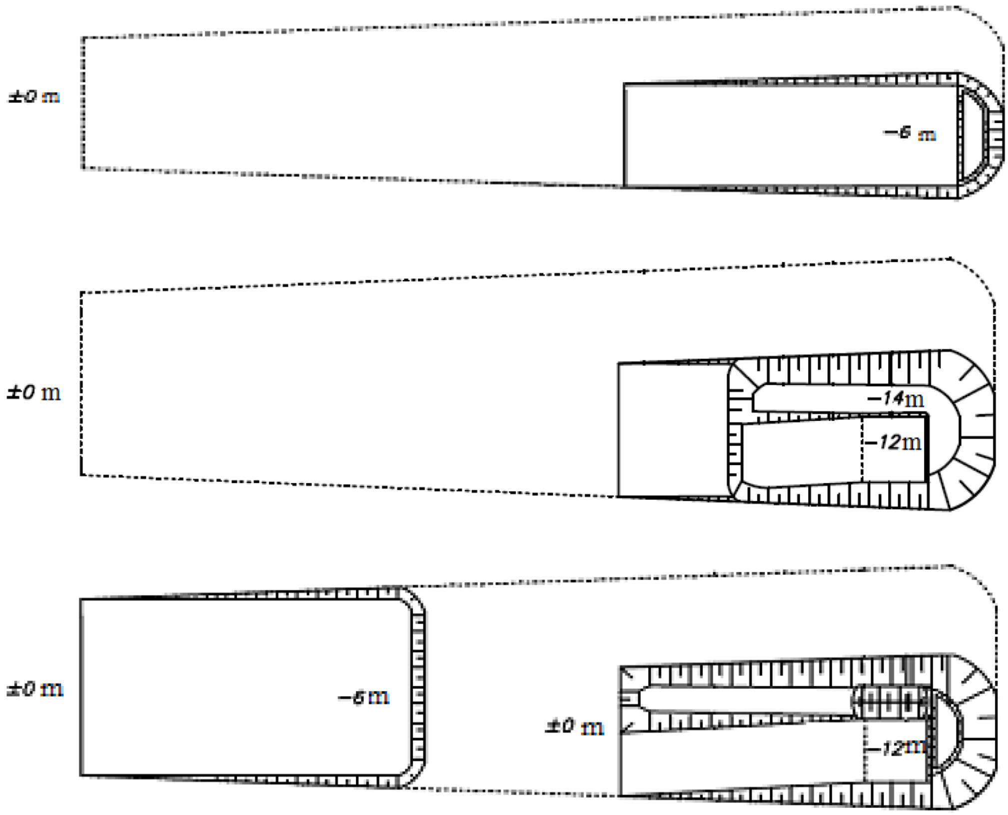

Figure 3. Implementation of the sequential technological scheme ($K_{p.f.}$=0,21, $K_{o.c.}$=0,4)

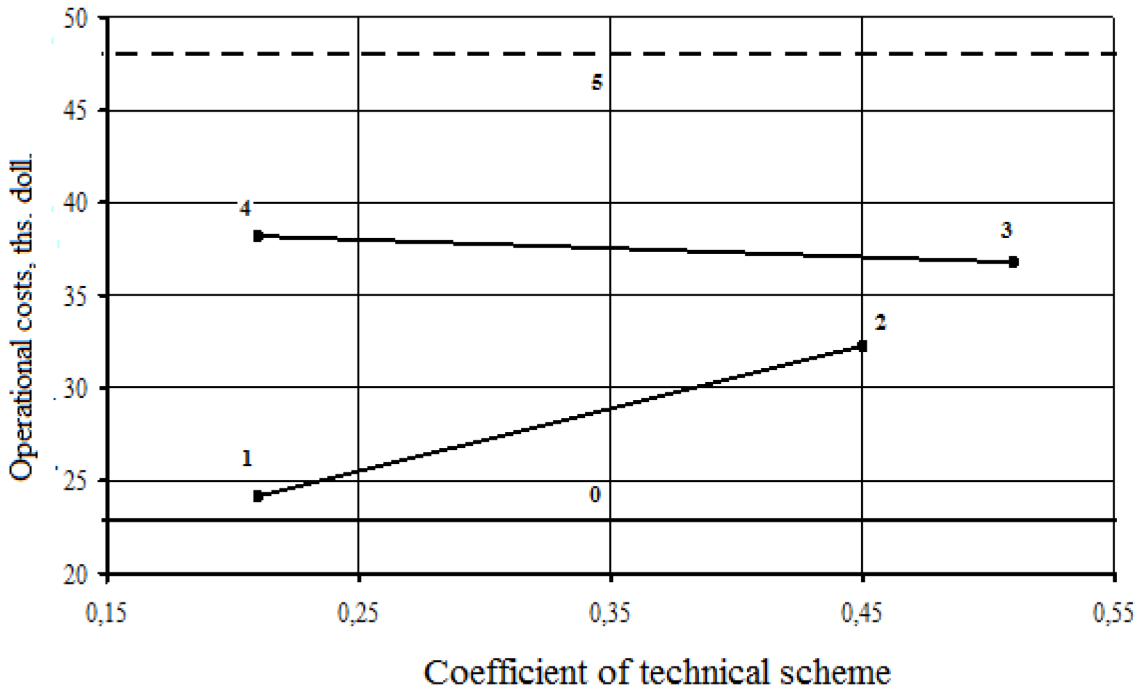

Figure 4. Operational costs for cross-loading equipment in case of: sequential (1,2) and parallel (3,4) schemes, operational costs for layerwise driving of a trench by front mechanical shovel under dry (0) and water-flooded (6) conditions are designated by continuous and dashed lines respectively

The horizon where the working trench, which length gives the possibility to begin works on its extension, has been driven is considered as the horizon prepared for operation [2]. Time of horizon preparation is calculated from the beginning of extension works of working trench in the overlying horizon to the completion of driving works of entry and working trenches in the underlying horizon [2]. In case of highway transport application, preparation of the horizon for operation is finished with creation of working trench with the parameters providing normal operation of the mining-transport equipment in the end of entry trench [2].

The necessary quantity of mining operations in the overlying horizon consists in extension of working trench and dispersal of shoulder to the distance providing possibility of construction of inclined trench in the underlying horizon, and creation of working trench in its face part considering the need of maintenance of working area [2].

Considering time necessary for decrease of depression cone of underground waters (t^1), and time of works on dispersal of an overlying shoulder and driving of inclined trench the underlying one (T), it is possible to determine rate of a pit deepening (v) by expression:

$$v = \frac{h}{T + t^1}, \text{ m/month}$$

Time of decrease of depression cone is determined by the solution of equation of Theis-Jacob [3, 4, 5]:

$$t = \frac{r^2}{2{,}25 \cdot a} \cdot e^{\frac{4 \cdot \pi \cdot k \cdot m \cdot S}{Q}}, \text{ days}$$

where Q – drain output, m^3/days;

S – decrease of level in observation point, m;

k - filtration coefficient, m/days;

m – layer power (water-bearing horizon), m;

km – water conductivity of layer (water-bearing horizon), m^2/days;

r – specified drain radius, distance to observation point, m;

a – formation pressure conductivity *($a^* = km/\mu^*$),* m^2/days;

R – radius of a depression cone, $R = 1{,}5 \cdot \sqrt{a \cdot t}$, m;

μ – water return of the horizon, unit fractions;

t – time from the beginning of well disturbance, days.

Technological calculations are carried out for front shovel and backhoe with a ladles capacity of $10m^3$ and $15m^3$ respectively. The water-bearing horizon, for which various values of depletion rate and redistribution of its stocks have been set, is considered. In calculations, the filtration coefficient varied in the range of 0.01 – 0.1 m/days with a step 0.01 m/days. Power of the water-bearing horizon was accepted equal to 200 m, water return was 0.07.

For each of schemes of trenches driving, two options distinguished by value of technological scheme coefficient have been considered. Calculation results are compared with trench driving by mechanical shovel along the full height of shoulder under dry conditions (Figure 5). For parallel diagrams, the values of coefficients of technological schemes 0.21 (4)

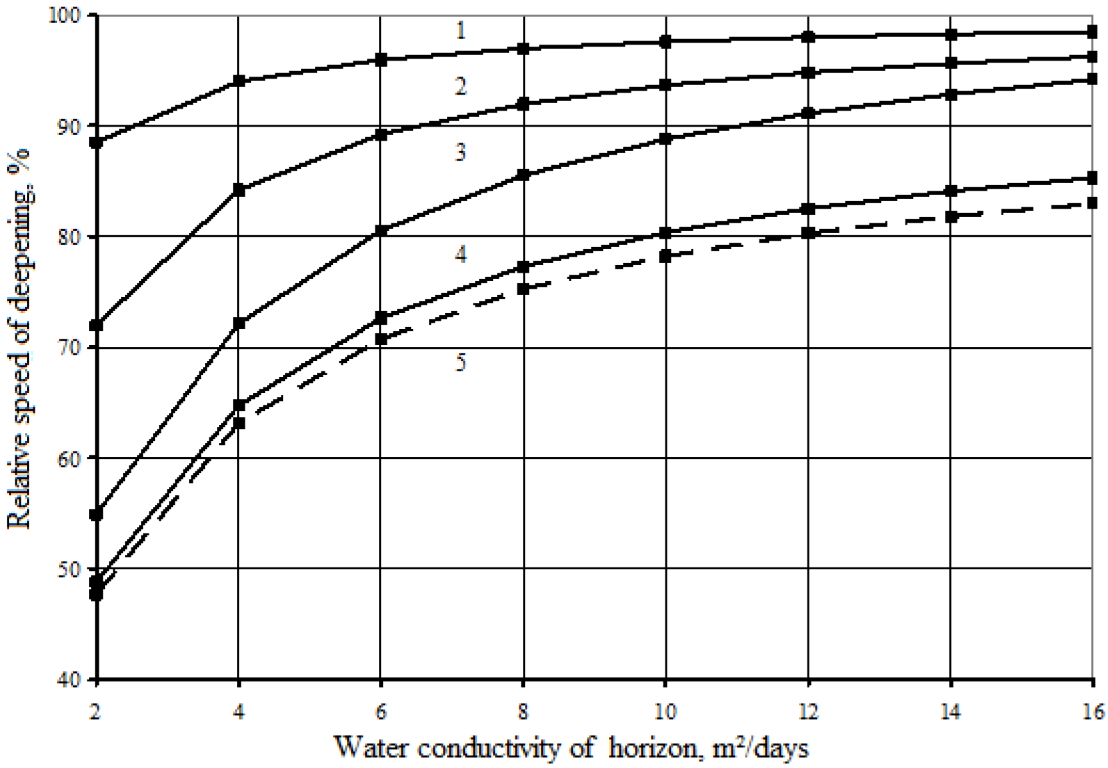

Figure 5. Dependence of relative rate of pit deepening on hydrogeological conditions of the horizon for sequential (1,2) and parallel (3,4) schemes and also for layerwise driving with use of the mechanical excavator (5)

and 0.51 (3), for sequential ones – 0.21 (1) and 0.45 (2) were accepted respectively.

The analysis of modelling results shows that the greatest rate of deepening is reached in case of application of sequential technological schemes of entry trenches driving. If $K_{p.f.}$ = 0.21, rate of deepening become closer to the deepening rate of characteristic for the mechanical shovel operating under dry conditions. Application of the existing layerwise schemes of trench construction by mechanical shovel leads to reduction of deepening rate by 30-50%.

In case of parallel schemes, the more construction works of trench the hydraulic excavator carries out, the higher deepening rate will be. It testifies that efficiency of their application is determined by amount of operations, which are carried out by the backhoe and does not depend on degree of adaptedness of trench construction operation organization to difficult hydrogeological conditions.

Conclusions and direction of further researches

In the paper, the problems of improvement of open mining operations technology when developing the deep horizons under difficult hydrogeological conditions are considered. The pit ore productivity depends on the deepening rate of a pit bottom. The theory of design of pits does not consider the fact that the possible rate of pit deepening depends on rate and duration of filtration processes in case of development of depression cone. In the paper, the determination technique of possible rate of pit deepening is developed; it considers hydrogeological conditions of horizons.

In the deep pits, the rate of deepening decreases because of use of front mechanical shovels at construction of trenches. Their operation efficiency decreases sharply under the conditions of water-flooded horizons. The authors have developed and proved the new combined schemes of trenches driving when opening the deep horizons of iron ore pits; the methods of determination of deepening rate of a pit are improved. The main idea of the developed technological schemes is use of trenches of reverse hydraulic excavators until creation of conditions for safe operation of front mechanical shovels. By the rate of trenches construction under the water-flooded conditions, the combined schemes become closer to indicators of front mechanical shovel during operation under dry conditions.

In the paper, relevant scientific problem of justification of technological schemes of opening and putting into operation of the deep horizons of iron ore pits under difficult hydrogeological conditions has been solved. Further researches will be directed on establishment of dependence of pit ore productivity on opening technology of water-flooded horizons.

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