Technology of working off pit walls areas, located in the area of funnels formation

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Abstract
The results of studies of technological schemes, allowing to carry out mining steep deposits, while ensuring the safety of technological processes are given.
Keywords: TECHNOLOGY, UNDERGROUND CAVITIES, OVERBURDEN, OPEN PIT MINING.

The problem of working off pit walls areas located in the area of the possible formation of funnels is particularly relevant for Krivyi Rih iron ore basin [1,2]. During deposit development by underground methods, significant amount of unliquidated cavities was accumulated. During expansion of pit borders, working sites will fall into one vertical plane with used deposits of rich ore. Such situation has developed on Gleevatskiy, Pervomayskiy, Inhuletskiy open pits [3,4].

The main requirements in the development of technology of working off of such areas, is to ensure the safety and efficiency of production processes [5, 6]. It is known that the process of entering the funnel on the surface occurs as a series of rockfalls of the roof of used deposits in the form of successive formation of the dome arches collapse. This happens up to certain limits, either to extinction of cavity, or until an instant breakout bedrock strata. Thus, cavity gradually decreases in volume and plan by a factor of loosening rocks, which allows to make a conclusion: in the case of filling a certain volume of cavity by the material, it will set the stage for further extinction of rocks that fell. The volume of material needed for bypassing may be determined from the expression:

$$V_p > V_c - V_b \cdot (K_l - 1),$$

where V_p – volume of rock filed into the cavity through the backfill drillhole, m^3; V_c – initial volume of cavity, m^3; V_b – volume of overlying bedrock over the cavity, m^3; K_l - coefficient of loosening rocks overlying.

Crushed waste rock is recommended to be used as filling material, which is extracted directly in open pit. Filling is fulfilled throw the slanted drillholes, drilled from the surface using special rigs. Such drill rigs are widely used for the construction of hollows for various purposes in underground mining. Technological schemes concerning filling of underground cavities with overburden, based on using mobile equipment, were developed.

Filling of the cavities are held on working platform (fig.1) of the bench, when mining works comes to cavity 7. Drilling and filling equipment is located in safe area behind safety berm 8. After drilling of filling drillhole, propelled crusher 1is transported to the point of works. Rock from working bottoms is delivered by trucks to the working platform and unloaded, forming alternately temporary storages 5.

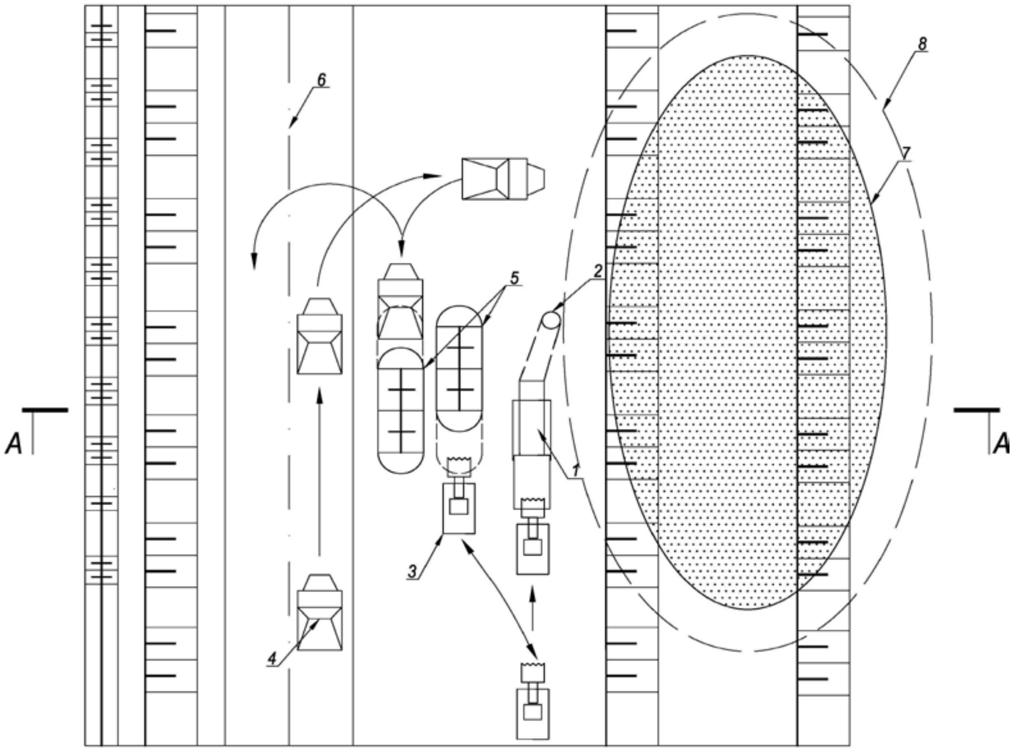

Figure1. The scheme of organization of work concerning filling cavities
1 – mobile crusher; 2 – orifice of filling drillhole; 3 – wheel loader; 4 – dump; 5 – temporary storage of rocks; 6 - axis of the road; 7 – projection exit cavity on the surface; 8 - safety berm.

Wheel loader weighs the rocks from the temporary storage, transports and unloads it into a hopper of mobile crusher. After finishing of filling works, mining operations can be continued. With such organization, operational annual costs will be defined as total cost of all kinds of technological filling operations.

It is necessary to consider shortening of the distance of transportation waste rocks as compared with the external dumping. It happens because of filling the cavities by waste rocks, which are directly excavated from the nearest to filling area bench. Additional costs for mining of undermined pit walls include the costs for filling cavities and exploration costs. Total discounted capital and operational costs for the entire period of mining will be:

$$C_s=\sum_{i=1}^{T}(D_{f.d.}\cdot c_{f.d.}+V_i\cdot(c_c+c_e+c_{t1}\cdot d_1-c_{t2}\cdot d_2-c_d))\cdot D_t+$$

$$+\sum_{i=1}^{T}(D_{e.d}\cdot c_{e.d.}+S_g\cdot c_g)\cdot D_t+C_c\cdot$$

where C_s – costs for ensuring the safety of technological processes, hrn; $D_{f.d.}$ – total depth of filling of drillholes in the i-th year, m/year; $c_{f.d.}$ – prime cost of drilling 1 of meter of filling drillhole, hrn/m; V_i – volume of waste rock used as filling material in the i-th year, m^3/year; c_c – prime cost of crushing of 1 m^3 of rock, hrn/m^3; c_e – prime cost of excavation of 1 m^3 of rock, grn/m^3; c_{t1} – prime cost of transportation waste rocks from bottom to filling area, hrn/t·km; c_{t2} – prime cost of transportation of waste rocks from bottom to dump, hrn/t·km; d_1 – distance from bottom to filling area, km; d_2 – distance from bottom to dump, km; c_d – prime cost of dumping, hrn/m^3; $D_{e.d.}$ – total depth of exploration drillholes in the i-th year, m/year; S_g – surface area of the pit walls, researched by means of geophysical exploration, m^2/year; $c_{e.d.}$ – prime cost of 1 meter of exploration drilling, hrn/m; c_g – prime cost of geophysical researches, hrn/m^2; C_c – capital costs for purchase of filling equipment, hrn.

$$D_t=\frac{1}{(1+E)^{t-1}}$$

where E – discount rate, %.

Estimation of economic efficiency of involvement in working off of undermined pit walls is fulfilled with the help of criteria of discounting profit:

$$P=\sum_{i=1}^{T}A_i\cdot\gamma\cdot P_c\cdot D_t-\sum_{t=1}^{T}(c_i\cdot A_i+c_o\cdot V_i)\cdot D_t-\sum_{i=1}^{T}C_s\cdot D_t,$$

where A_i – mined ore in the i-th year, t/year; γ – iron concentrate output from 1t of iron ore; P_c - the price for 1t of iron ore concentrate, hrn/t; c_i – prime cost of 1t ore extraction, hrn/t; c_o - prime cost of 1m^3 of overburden extraction, hrn/t; V_i – volume of mined waste rock in the i-th year, m^3/year; C_s – costs for ensuring the safety of technological processes in the area of funneling in the i-th year, hrn/year.

The approbation of results was made on Gleevatskiy open pit PJSC "CGOK". The analysis of current condition of mining works and undermining of eastern pit wall of open pit was fulfilled. On the base of data given above concerning previously formed funnels, the coefficient of massive destruction in different parts of eastern pit wall was determined. It was made for further determining of existing danger of underground cavities. After analysis of mine surveying data, using recommendations [7] 17 danger areas in project contours of open pit were determined.

In accordance with approved balance reserves in the eastern part of the open pit, 33602 tons of iron ore are located.

Within the project of open pit working off, annual volumes of ore and overburden mining in the eastern side for determining of cost-effectiveness of its involvement were defined.

At a discount rate of 12% and the price for the iron concentrate 850 hrn/ton the profit as a result of involvement the eastern side Gleevatskyi open pit will be 357,6 million hrn.

Conclusions

Proposed technology of organization of mining works in the area of possible funneling allows working off the pit walls of open pit and expands its borders to mine all balance iron ore.

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