 https://doi.org/10.1051/e3sconf/202127801020

Management of Excess Mined-Out Space of Quarry Fields of Coal Open Pit Mines

Alexei Selyukov[1,*], *Tatiana* Gvozdkova[2,] and *A.J.S. (Sam)* Spearing[3]

[1] T.F. Gorbachev Kuzbass State Technical University, Department of open pit mining, 650000 Kemerovo, 28 Vesennya st., Russian Federation
[2] T. F. Gorbachev Kuzbass State Technical University, Mezhdurechensk branch, 652881, 36 Stroiteley st., Mezhdurechensk, Kemerovo region-Kuzbass, Russia
[3] School of Engineering & Technology, Central Queensland University, Rockhampton North, Bruce Highway, Rockhampton, QLD 4702, Australia

Abstract. Regardless of the applied technology of coal mining, a technogenic resource of the open pit is formed – excess mined-out space. Excessive mined-out space should be understood as a part of the internal space of a pit that is not used for placing overburden in dumps. The excess mined-out space in the plan is limited by the following: on the flanks of the quarry field and along the uprising by the limiting contour of the quarry, along the inclination – by the possible position of the slope of the dump layer, as close as possible to the working area. The lower boundary corresponds to the position of the formed dumps, the upper one – to the marks of the dominant relief. The article presents a method for reducing the excess mined-out space by means of the patterns of spatial development of objects "quarry field – dump of overburden".

1 Introduction

An increase in the burden on the environment is integral to the development of mining [1-2]. Kuzbass (Western Siberia, Russia) is no exception, in which the increase in coal production in 2000-2019 to the level of 220 million tons led to the extraction of almost 2 billion m^3 of rock mass annually [3-4]. As a result, huge quarries are only partially filled with internal dumps of overburden, and most of it are located in internal dumps [5]. The consequence of this is the emergence of excess mined-out space, which turns the terrain in the area of high concentration of open-pit mining into a "lunar landscape" [6-7]. This leads to the emergence of significant environmental problems [8-9], which, along with the issues of improving the safety of mining operations [10-11], are key for the coming decades [12-13].

2 Materials and Methods

E.V. Eremenko [14] gave the following definition to the term "excess (unfilled) mined-out space" – the difference between the receiving capacity of the mined-out space of a coal open pit mine and the recoverable volumes of overburden. In other words, the minimum amount

* Corresponding author: sav.ormpi@kuzstu.ru

of excess worked-out space is the current land capacity of a surface mine, the maximum value of which is the operational land capacity.

As noted earlier, with this method of open pit mining, the excess mined-out space will be equal to the volume of the quarry. Obviously, the longer the operation life of the open-pit mine with a deep longitudinal development system, the more progressive the growth rate of the excess mined-out space.

Then, proceeding from two theoretical provisions – the contour development of the quarry field and the external dump, the mutual orientation of their development – the numerical calculation scheme can be represented in the form of a graphic image shown in Fig. 1.

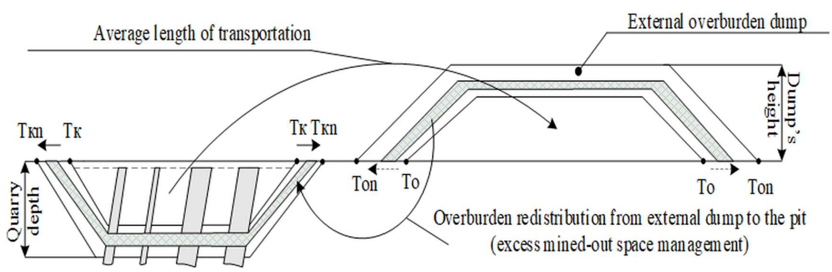

Fig. 1. A schematic diagram for the numerical evaluation of the management of the excess mined-out space of quarry fields of coal surface mines by means of the contour development of the quarry field and an external dump.

In Fig. 1 the following designations are adopted: T_k, T_o – respectively, the initial position of the contours of the open pit field and the external dump; $T_{кп}$, $T_{оп}$ – respectively, the boundary contours of the open pit field and the external dump; the arrows show the vectors of velocities and the directions of movement of the contours.

According to the scheme, the contour development of a quarry field and an external dump of overburden is represented as the co-directionality of two objects lying in the same horizontal plane. Since two objects spatially move towards each other, the maximum area between objects can be determined as a function of the time of closing the space between them. Assuming a fixed initial position between the objects by means of the weighted average distance of transportation to the external dump, we determine their maximum distance from each other. Then the area of objects can be found as a function of *S* at the initial moment of time:

$$S_O = (L_{TP} - B) \cdot L \tag{1}$$

where: S_0 is the maximum value of the area of objects (m^2);
L_{TP} is the weighted average distance of transportation to the external dump;
B is the width of the open pit on top, (m or km);
L is the length of the quarry field at the top (m or km).

Let us transform expression (1) with respect to the spatial movement of the contours at any time interval:

$$S_{(t)} = S_O - (V_1 + V_2) \cdot t \cdot L = (L_{TP} - B) \cdot L - (V_1 + V_2) \cdot t \cdot L \tag{2}$$

where: V_1, $V2$ are respectively the rate of advancement of the contours of the quarry field and the external dump, m / year;
t is the period of moving the contours.

3 Results and Discussion

According to expressions (1) and (2), graphical dependencies for establishing the mutual influence of the contour development of a quarry field and an external dump and an enlarged scheme for establishing the proposed method for reducing the excess mined-out space of sections with motor transport technology were built (Fig. 2).

Calculations have established (Fig. 2) that for any range of overburden transportation distance to external dumps from 2 to 5 km, and parameters of open pit fields with a width of 500 to 2000 m and a length of 2000 to 12000 m (which corresponds to the actual data of Kuzbass open pits), the maximum calculated values of the areas can reach up to 550 million m^2. In other words, it is the maximum area value occupied by the quarry field S_0.

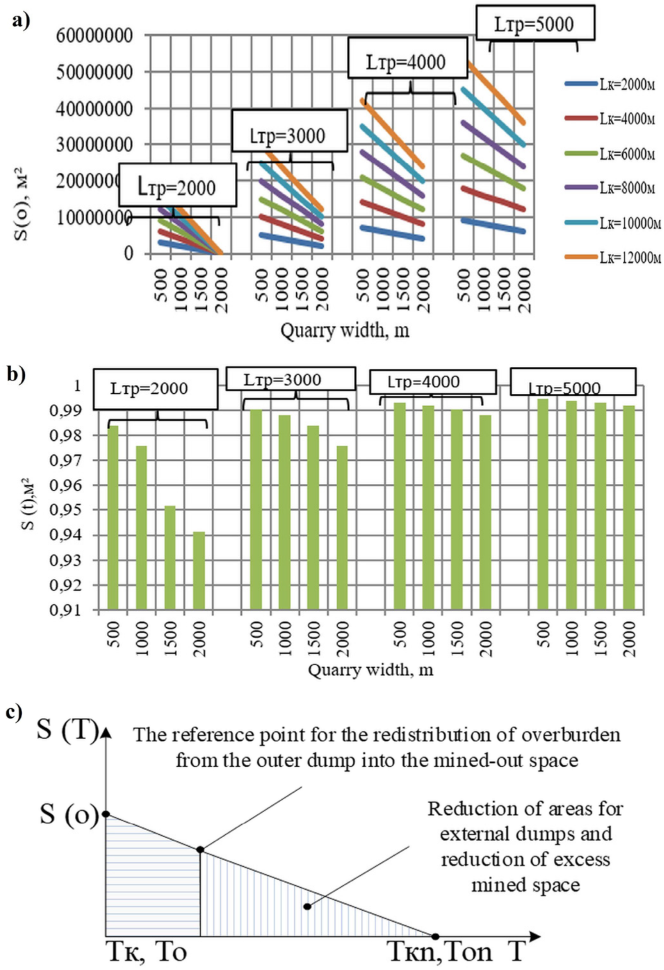

Fig. 2. Graphical diagram of the numerical ranges of the distribution function S0 depending on the parameters of the quarry field (length, width) and the weighted average distance of transportation (a); the histogram of the distribution of the area reduction (fraction of a unit) for the required period of time (b); an enlarged scheme to regulate the reduction of the areas for external dumps and the reduction of the unoccupied mined-out space (c).

With the operation of the enterprise, the contours of the quarry field or the area of unoccupied mined-out space increase in direct proportion until the meeting of two objects lying on the same plane, and vice versa, the area between the two objects – "open pit field" and "external overburden dump" – is reduced.

Then, in the time interval from T_k (T_o) to T_{kn} (T_{on}), we set the time S_t, at which the area of the excess mined-out space of the opencast field is reduced. The closer this point is to the values of $T_{кn}$ (T_n), the smaller the area of the open pit area occupied by overburden storage, and vice versa, the closer to S_0, the larger the area.

The total area enclosed between the segments S_0 and T_{kn} (T_{on}) and the abscissa axis T after the reference point means the amount of reduction of the unoccupied mined-out space.

Analysis of the factors affecting the excess mined-out space under the conditions of the existing open-pit mines shows that the mining method is the fundamental moment in the growth of the excess mined-out space (Fig. 3).

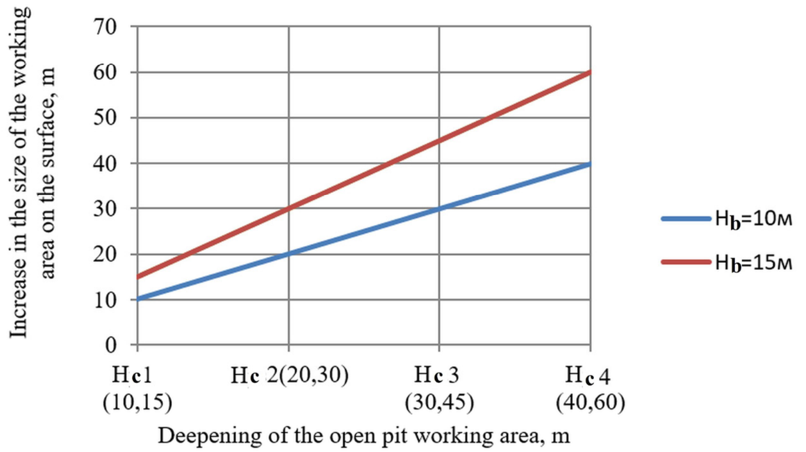

Fig. 3. Increases in the size of the working area of a quarry field along the surface, depending on the deepening of mining operations.

Among the more representative factors affecting the excess mined space, the development system can be distinguished. At the same time, in the general technical policy of coal producers, there is a steady trend towards increasing the volume of internal dumping during the development of inclined and steep coal deposits. These technologies are aimed at eliminating the aforementioned disadvantage of open pit mining. In order to reduce the residual mining, it is necessary to ensure a decrease in the growth of the volumes of the excess mined-out space, even due to internal dumping. Such technological solutions can be achieved when the mined-out area of a quarry field is used as a container for an internal dump.

Methods for reducing the excess worked-out space are based on the following principles:
• determination of the reasons influencing the growth of excess mined-out space, and possible ways of elimination;
• quantitative assessment of the spatial development of two aggregate objects "open pit field" – "external dump";
• assessment of the receiving capacity of the external overburden dump;
• ways to reduce the excess mined-out space with the reduction of the unfilled mined-out area of the quarry field.

The total volume of excess mining will be equal to the ratio between the volumetric figure of the opencast field and the maximum share of internal dumping. Consider an approach based on a graphical scheme and applied to the development conditions of inclined and steeply dipping coal seams of Kuzbass.

4 Conclusion

Thus, the management of the placement of overburden in the internal dump, on the one hand, will be a tool for reducing the excess worked-out space, and on the other hand, it will, to a certain extent, reduce the restrictive development of the location of overburden by external dumps and their further development.

References

1. M. Cehlár, P. Rybár, J. Mihók, J. Engel, Journal of Mining and Geotechnical Engineering, **1**, 66-74 (2020) DOI: 10.26730/2587-5574-2020-1-66-74
2. M. Yazevich, O. Kalinina, O.Zhironkina, E3S Web Conf. **134**, 03004 (2019)
3. V.F. Kolesnikov, J. Janočko, Journal of Mining and Geotechnical Engineering, **2**, 42-74 (2020) doi: 10.26730/2618-7434-2020-2-42-74
4. S. Zhironkin, A. Selyukov, M. Gasanov, Energies, **3(13)**, 3305 (2020)
5. T.V. Kiseleva, V.G. Mikhailov, Economics and Innovation Management, **4**, 70-78 (2018) DOI: 10.26730/2587-5574-2018-4-70-78
6. A. Selyukov, R. Rybár, E3S Web Conf. **105**, 01043 (2019)
7. A. Selyukov, P. Blištan, S. Jacko, V. Bauer, E3S Web Conf. **41**, 01031 (2018)
8. A. Selyukov, V. Ermolaev, I. Kostinez, E3S Web Conf. **21**, 01027 (2017)
9. A.V. Selukov, *Advanced technology based on new technological and organizational principles of spatial development of front of mining operations at open pits* (Taishan Academic Forum - Project on Mine Disaster Prevention and Control, 2014)
10. D. Szurgacz, M. Tutak, J. Brodny, L. Sobik, O. Zhironkina, Energies, **13(17)**, 4538 (2020) DOI: 10.3390/en13174538
11. M. Tutak, J. Brodny, D. Szurgacz, L. Sobik, S. Zhironkin, Energies, **13(18)**, 4891 (2020)
12. A.V. Selyukov, Journal of Mining Science, **51(5)**, 879-887 (2015)
13. A.V. Selyukov, Bulletin of the Tomsk Polytechnic University, Geo Assets Engineering, **326(12)**, 60-71 (2015)
14. E.V. Eremenko, A.I. Kosolapov, GIAB, **S1-1**, 249-258 (2015)