Criteria for the difficulty of working out coal-bearing zones of quarry fields

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Abstract. Coal-bearing zones of open pit fields are represented by formations of coal seams from inclined to steep bedding with unstable thickness, both in dip and strike with different dip angles even within the same strata, with varying rock inter-layers and strength. In addition, most coal seams have a complex structure, including rock layers inside. In most cases, there is an uneven distribution of coal seams, and, consequently, coal reserves over the area of quarry fields. In this regard, for the analysis of quarry fields, there is a need to select criteria for assessing the complexity of coal-bearing zones for the purpose of systematizing them and choosing directions for constructing technological schemes for excavation and loading operations and mining methods.

1 Introduction

The development of technical equipment and the scale of open pit coal mining draws increased attention to the Kuzbass open pits, as the Kemerovo Region (Western Siberia, Russia) has limited agricultural resources [1-3]. The deep-seated longitudinal single and double–sided system for developing inclined and steep coal deposits that is currently widely used contributes to the progressive disruption of the earth's surface, both by mining operations and external dumps [4-6], while the specific land intensity reaches 55 ha per 1 million tons of coal. The disadvantages also include the long range of transportation of overburden rocks to the dump, both by rail and by road. All this increases the cost of coal mining and reduces its competitiveness in the market [7-8].

The negative impact on the environment can be minimized by changing the mining order of the existing open pits of Kuzbass coal basin, while using mining methods with internal partial or complete dumping. If this is not foreseen at present, then all sections in the coming decades will be limited by their own dumps and their further development will be problematic.

Constraining factors for the development of new technology are: the lack of options for the formation of initial mine workings and new varieties of development systems with internal dumping in the conditions of longitudinal deep, and recommendations for the formation of technological stages and transition schemes; substantiation of mining

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technology in the transition period and during the completion of quarry fields and, ultimately, insufficient knowledge of the transformation of deep longitudinal into transverse mining method in the mode of an active section.

Therefore, on the existing open pits of the Kuzbass coal basin, there has been a tendency to use systems for the development of inclined and steep deposits with the placement of overburden in the worked out space. At the same time, the studies carried out on the above mining method are based on the use of high-cost technological systems, however, at the same time, the open pit mining conditions allow the use of direct dumping technology [9-11].

2 Materials and Methods

Currently, the mining–and–geometrical analysis of quarry fields mainly uses the indicator "stripping ratio". However, this indicator does not characterize the difficulty of the quarry fields mining.

In this regard, the following criteria are proposed for assessing the technological complexity of the quarry fields mining.

1. The density distribution of coal saturation of the quarry field. The physical meaning of this criterion is to assign coal reserves in blocks or in the entire quarry field to the total volume of P_{yi} blocks or P_y quarry fields.

$$P_{yi} = \frac{V^{b}_{yi} \cdot \rho^{b}_{yi}}{V^{b}_{yi} + V^{b}_{ni}} \tag{1}$$

$$P_{y} = \frac{V^{kp}_{y} \cdot \rho^{kp}_{y}}{V^{kp}_{y} + V^{kp}_{n}} \tag{2}$$

where V^{b}_{yi}, V^{b}_{ni} – is the volume of coal and rocks, respectively, in the *i–th* block, m^3; ρ^{b}_{yi} – the average density of coal in the *i–th* block, t / m^3;

$V^{kp}_{y}, V^{kp}_{n}\ V^{kp}_{y}, V^{kp}_{n}$ – the volume of coal and rocks, respectively, within the boundaries of the quarry field, m^3; – the average density of coal within the boundaries of the quarry field, t / m^3.

Dividing the numerator and denominator by the result of multiplication and by $V^{b}_{yi}, \rho^{b}_{yi}$, we obtain:

$$P_{yi} = \frac{1}{\frac{1}{\rho^{b}_{yi}} + K^{cp}_{Bi}} \tag{3}$$

$$P_{y} = \frac{1}{\frac{1}{\rho^{kp}_{y}} + K^{cp}_{b}} \tag{4}$$

where K^{cp}_{Bi} and K^{cp}_{B} are the average stripping ratio within the boundaries of the *i–th* block and the career field, respectively.

This criterion can be used when choosing a technological strategy for developing a quarry field and a development system.

2. The share of the coal-bearing zone in the total quarry field. The essence of the criterion is to assign the volume of the coal-bearing zone to the total volume of the quarry field, i.e.:

$$\delta_{cb} = \frac{V_{cb}^{kp}}{V_{y}^{kp} + V_{n}^{kp}} \tag{5}$$

where V_{cb}^{kp} is the volume of the coal-bearing zone within the boundaries of the quarry field, m^3.

This criterion is used in assessing the overall efficiency of mining a quarry field using various technological options.

3. Brand composition of coals in the layers of the coal-bearing zone and their share in the total reserves of the quarry field. The criterion is supposed to be used when planning mining operations and evaluating the effectiveness of technological options for mining quarries.

4. The angle of incidence of the formation. This indicator affects the choice of technological schemes for excavation and loading operations and the structure of the excavation and transportation complex.

5. The thickness of the rock interlayers. The criterion determines the possibility of selective extraction of coal seams of the strata, characterized by the degree of proximity.

6. The degree of proximity of coal seams. According to this criterion, all the layers of the strata are divided into close and dispersed. Close coal seams of inclined and steep dipping include seams between which the thickness of the rock interlayer does not allow preparation for their excavation by working cutting trenches from the hanging side. The dispersed seams are characterized by the possibility of their separate excavation with the cutting of a trench from the side of the hanging side. Close coal seams of a flat bedding in the transport zone include seams whose distance between them does not provide the formation of a transport platform for a dead end turn and the movement of trucks.

This criterion is decisive in deciding on the technological option of mining coal seams and the selection of mining and loading and transport equipment.

7. The proportion of close and dispersed coal seams in their total number in the coal–bearing zone of the quarry field. This indicator is used in a comparative evaluation of the efficiency of technological schemes of excavation and loading operations by complexes of excavation and transportation equipment and the overall efficiency of mining coal–bearing zones of open pit fields.

3 Analysis of coal-bearing and coal-less zones of the quarries of Kuzbass

Open pit mine "Kedrovskiy." For the “Main field” section the share of the coal–bearing zone in the quarry field is 0.48. The density of coal saturation is 0.129 t/m^3. The mutual position of the seams within the quarry field is: close – 27% and dispersed – 15% of the volume of the quarry field. For "Latyshevsky field": the density of coal saturation – 0.11 t/m3; share of the coal–bearing zone – 0.59; close seams – 33%; dispersed – 10%. For "Khorosheborsky field," the density of coal saturation is 0.136 t/m^3; Fraction of coal–bearing zone – 0.51; close seams – 30%; dispersed – 10%. As a whole, the weighted averages are: density of coal saturation – 0.125 t/m^3; fraction of coal–bearing zone – 0.53; close seams – 30%; dispersed – 8.3%.

Open pit mine "Bachatsky." "Block North." Density of coal saturation – 0.136 t/m3; Fraction of coal–bearing zone – 0.59; At that, the close seams – 13%; dispersed – 9%. It should be noted that when calculating for 2–3 weighted average geological sections, seams with thickness of 1m and less were taken into account. "Central Block." Of the quarry field blocks analyzed, this site is the largest. Thus, the fraction of the coal–bearing zone is 0.62; Density of coal saturation – 0.151 t/m^3. At the same time the share of close seams – 32%, and dispersed – 4%. "Southern block" density of coal saturation – 0.128 t/m^3; Mutual position of the close seams – 29%; dispersed – 10%. Weighted average characteristics of parameters of the carbon–bearing zone. Density of coal saturation – 0.138 t/m^3; fraction of coal–bearing zone – 0.57; close seams – 24.6%, dispersed – 7.6%.

Open pit mine "Krasnobrodsky." "Krasnobrodsky field" of the section. For this field, the density of coal saturation within the boundaries of the quarry field is – 0.133 t/m^3; Share of coal-bearing zone in quarry field – 0.53; close seams – 38%; dispersed – 9.3%. "Nowergeyevsky Field." For this field the density of coal saturation – 0.121 t/m^3; fraction of carbon–bearing zone – 0.48; close seams – 26%; dispersed – 8.9%. The average values for the two fields of the section are: density of coal saturation – 0.127 t/m^3 of the coal-bearing zone – 0.5; dispersed seams – 9.1%; close – 32%.

Open pit mine "Osinikovsky." When considering the field of this section, the following weighted averages are established: density of coal saturation within the field boundaries – 0.125 t/m^3; Share of the coal-bearing zone in the quarry field – 0.59; close seams – 8%; dispersed – 22%.

Open pit mine "Vakhrushevsky." Parameters characterizing the coal-bearing zone: density of coal-bearing – 0.116 t/m^3; zone's share within the quarry field – 0.46; close seams – 32%; dispersed – 13%.

Open pit mine "Kaltanskiy". Density of coal saturation within the field boundaries – 0.119 t/m^3; fraction of coal-bearing zone – 0.45; close seams – 18.5%; dispersed – 21%.

4 Conclusion

The effectiveness of transverse mining methods depends to a large extent on the share of internal dumping in the total opening volume in the boundary contours of the open pit, the method of internal dumping, the parameters of the quarry field and the development options determining the volume of internal dumping. The volumes occupied by mining taking into account the developed space do not exceed 10%–30% of the total volumes of the quarry field.

The control over mining operations can be achieved by concentrating them in a coal-bearing zone. The duration of the technological transition depends on the depth of the seams bedding, the thickness of the strata, the productivity of the technical complex. The annual production capacity and for the cuts of Kuzbass is 8–11 years (dipping-and-longwork mining method) and up to 2–6 months (shuttle-and-layer mining method). Technologically, the transition to internal dumping is possible when the level of reserves covers the duration of the transition with compliance with the criteria of the algorithm for selecting the location of workings.

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