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## **DIMENSIONING SPECIFICS OF THE PRODUCTION CAPACITY OF UNDERGROUND COAL MINES IN SERBIA**

Todorović Vladimir<sup>1</sup>, Tošić Dražana<sup>2</sup>, Trivan Jelena<sup>2</sup>

<sup>1</sup>*JPPEU Resavica, Serbia, email: [todorovicvladimir78@gmail.com](mailto:todorovicvladimir78@gmail.com)*

<sup>2</sup>*University of Banja Luka, Faculty of Mining Prijedor, Bosnia and Herzegovina*

### **ABSTRACT**

Sizing the production capacity of underground coal mines is an extremely complex task with a number of specifics that must be taken into account when designing the mines. The main factors are the specific natural-geological conditions of the deposit, which determine the application of an adequate excavation system followed by organizational factors, which in combination gives the most favorable production, economic and safety parameters.

This paper presents the specifics of production capacity design in active underground coal mines in Serbia, based on a comprehensive analysis of the influencing factors. Of special importance is the ranking of the impact of natural and geological conditions on the excavation system, with four groups with the qualitative analysis.

*Key words: mine, coal, excavation system, method of excavation, pillar excavation, chamber excavation.*

### **INTRODUCTION**

The production capacity of mines (shaft) is a basic parameter in underground coal mining and it determines the intensity and dynamics of work, organization of work and financial performance of mines. The quantitative value of production capacity most directly depends on the applied excavation system, i.e. the method and technology of excavation.

Basically, the capacity of the mine is affected by changing general and specific conditions. Natural-geological conditions in deposits that belong to the specific conditions, are carriers of risk in terms of possible mismatch between the projected capacity and the real in space and time of exploitation of one coal deposit. This requires the need for detailed study and consideration of each deposit and the selection of technical solutions that are adequate primarily to natural-geological conditions.

The introduction of modern technical and technological solutions, which are characterized by an increased level of mechanization, automation, remote monitoring and control, in conditions of low research and study of natural and geological conditions in the deposit can lead to failure and cause the significant production, economic and safety consequences.

On the one hand, the natural-geological characteristics of the deposit are decisive for the design and selection of technical-technological solutions, i.e. plants and equipment for all technological phases and work operations, and at the same time require continuous adjustment of work methods and organization to specific natural-geological conditions. The oscillations of the production capacity in a relatively wide range are inevitable.

These changes in the production capacity are proportional to the changes in general and specific conditions of exploitation. From this comes the logical conclusion that the technical-economic valorization of the application of appropriate excavation solutions should be performed through the parameters of average-probable production capacity, which implies the application of average values of input data on the working environment, provided that the most unfavorable values of technical parameters do not exclude the application of appropriate technical-technological solution.

The definition of the term "average conditions" refers to the need that the all influencing factors of the working environment must be researched and tested in a prescribed manner by applying the appropriate comprehensively developed scientific methods. In this paper, within the subject research, methods of mathematical modeling, experimental methods of analysis and synthesis were applied. Active underground coal mines in Serbia were taken as the framework of this research, with the aim of contributing to the calculation of production capacity and studying the rank of the influence of natural-geological conditions on the choice of the excavation system.

This issue has been dealt with by researchers in Serbia [1,2] mainly related to the conditions of thick coal seams.

#### NATURAL-GEOLOGICAL CONDITIONS AND APPLIED EXCAVATION SYSTEMS IN COAL MINES IN SERBIA

The present complex natural-geological conditions in the coal deposits in Serbia influenced the choice of technological solutions for excavation, so that today in all active mines pillar and room and pillar methods are applied in different variants. The deposits are dominated by layered and inclined structures with tectonic disturbances that influenced the formation of irregular shapes of limited exploitation areas with short lengths of excavation fields, by strike and dip, with frequent changes in the thickness of coal seams and their deposition elements [3].

Coal layers are of variable thickness from 1m to 40m with incline of 5 ° to 45 ° and one to two exploitable layers are usually developed in the deposits. The surrounding rocks of coal seams, the immediate floor and roof, in almost all deposits are made of rocks with a predominant content of clay components, which is unfavorable from the aspect of construction and supporting of mining rooms and dimensioning of excavations. These rocks have lower values of the geomechanical characteristics, which greatly limited the possibility of using large mechanized production systems.

According to the depth of coal seams, most deposits belong to the group of mines with an average depth of up to 500 m, with a few exceptions. Regarding to the hydrological conditions, it can be concluded that there are a small inflows of water into the mining rooms. Other conditions related to safety: gas content, self-ignition of coal and characteristics of coal dust (explosiveness, flammability and aggressiveness) do not have a greater influence on the underground mining works in shafts with the usual safety measures. So far, numerous and specific solutions have been applied in the mines, pillar and pillar and room excavation with blasting technology, which is characterized by:

- wide application due to the great possibility of the working front geometry of the excavation front and the tactics of excavation in the complex conditions of exploitation,
- deconcentration of excavation and preparatory works,
- low excavation capacity, low productivity and the need for a larger number of excavation units,
- low degree of mechanization on excavation units,
- high participation in the construction of the preparatory rooms.

In the period from 1977 to 1992, in some mines, with breaks, the methods of mechanized longwall excavations were applied, whereby the production and economic conditions differed from case to case, but in any case more favorable than those achieved by pillar excavation systems [4]. The principle of the pillar excavation method consists in excavating the prepared inclined pillars by carry the stope from the raise on the both sides. The basic preparation for this method consists in the construction of the rooms by providing a layer-excitation bases by which the excavation field (excavation block) is divided after falling on the inclined pillars. The construction of these rooms is done with drilling and mining technology and supported with a steel, alternatively with wooden support [Figure 1] [9].

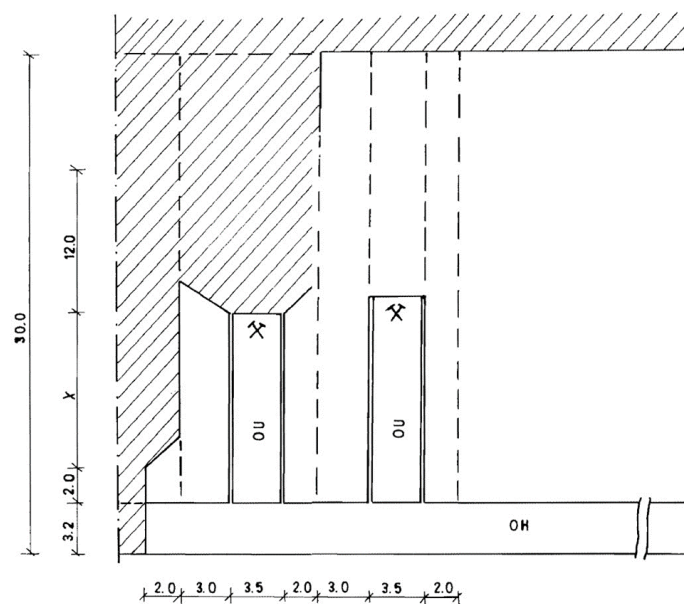


Figure 1. Disposition of excavation in one excavated pillar [9]

The excavation of coal seams by the room method has application in the conditions of a compact layer and an immediate roof that can withstand with the higher specific loads under pressure. The advantage of applying this method is a simple and efficient way of supporting the rooms with a hanging support, which creates favorable conditions for increasing the speed of excavation progress and high excavation effects.

The method offers wide possibilities in terms of the choice of technological solutions and methods of excavation work, the combination of mobile multifunctional machines for excavation, loading and transporting of coal, as well as different variants of work organization [5]. Pillar excavations usually have the shape of regular mutually parallel rooms-excitation pillars.

Preparation for the room method consists of a wide preparation - making a transport and ventilation drifts of the excavation field by strike of layer and narrower preparation - a roof and floor raise excavation, which eventually merge and in the joint the stope expands and forms an excavation front. Coal production is performed by blasting technology, where the coal gravitationally falls into the floor layer and is transported by scraper conveyor. The technology of mechanized excavation with complex mechanization on longwall excavations is the basic development direction in coal excavation by underground exploitation system.

The basic preparation for these excavations is reduced to the construction of a transport and ventilation drifts by strike of seam to the boundary of the excavation field, where they are connected by making a raise in which the equipment is installed. Figure 2 shows a schematic layout of a longwall mine [10]. The length of the longwalls ranges from 50 to 300 m, and in the mines in Serbia it averaged 80 m.

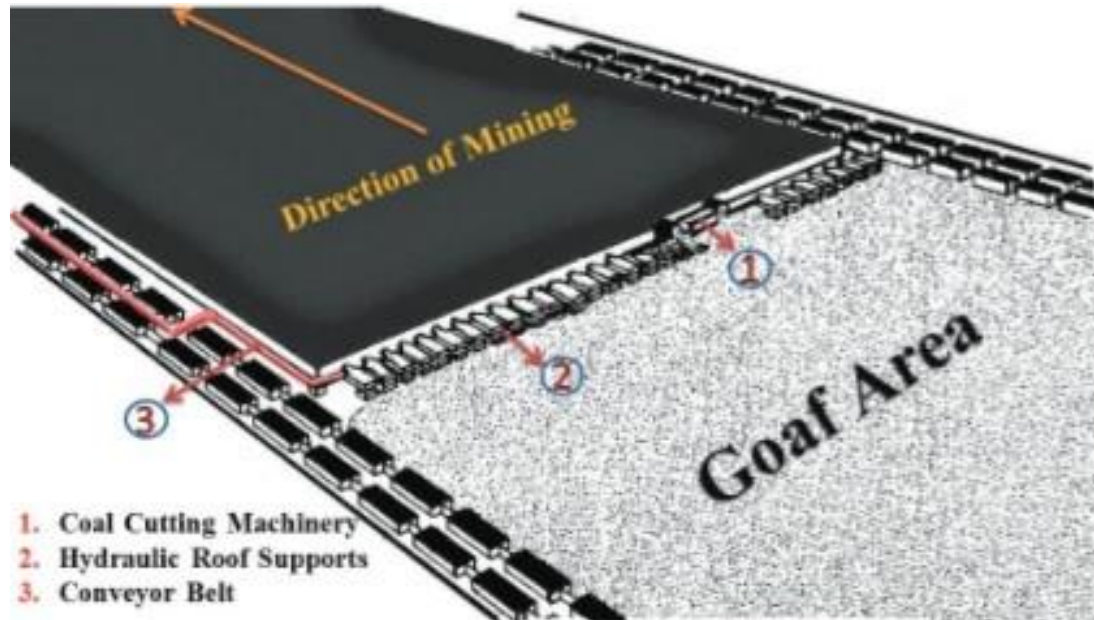


Figure 2. Schematic layout of a longwall mine [10]

Complex mechanization on a mechanized longwall consists of:

- self-propelled hydraulic support, of different types and dimensions
- digging machine by cutting or scraping
- high pressure hydraulic plant
- front and gate conveyor
- power plant

These parts of the complex are interconnected mechanically and functionally with the aim of complete synchronization of the work operations. Longwall excavation is applied according to the principle of horizontal concentration for seams up to 5 m thick, while for larger thicknesses the principle of vertical concentration is applied in the variants:

1. mechanized excavations according to the principle of horizontal concentration in several belts
2. mechanized excavations according to the principle of vertical concentration with variants:
  - underlying and overburdening in several, and
  - underlying and overburdening in one operation

The operation of longwall excavations can be with single-wing or double-wing excavation schedule, outbye or inbound.

Based on a comprehensive review of natural-geological conditions of exploitation in production deposits-mines and review of applied excavation systems, the limitations in the application of certain technological solutions of excavation are defined, and the qualitative rank of impact is determined, which is shown in Table 1. [5].

Table 1. Rank of the influence of natural-geological conditions on the choice of the system of excavation

Excavation system		CATEGORY-RANK OF INFLUENCE OF NATURAL-GEOLOGICAL CONDITIONS			
		I Determining	II Additional	III Limiting	IV Exclusive
Principle of excavation concentration	HK	1. Layer thickness up to 5	1. Dip angle	1. Rock burst 2. Gas and material expansion	
	VK	2. Layer thickness over 5 m	1. Dip angle	2. Tendency to coal self-ignition	1. Layer thickness less than 5m
METHOD OF EXCAVATION	Longwall Mining (HK)	1. Layer thickness up to 5m 2. Rational length of the excavation field to strike and dip	1. Dip angle 2. Physical and mechanical characteristics of the coal seam and surrounding rocks	1. High methane content 2. The size of coal reserves 3. Physical and mechanical characteristics of the floor	1. Irrational length of the excavation field to strike and dip
	Longwall Mining (VK)	1. Layer thickness over 5 m 2. Rational length of the excavation field to strike and dip	1. Dip angle 2. Physical and mechanical characteristics of the coal seam and surrounding rocks	1. Abundant in water 2. Tendency to coal self-ignition 3. High methane content 4. Size of coal reserves	1. Irrational length of the excavation field to strike and dip
	Room method	1. Layer thickness over 5 m 2. Strength and compactness of immediate roof	1. Changes in layer thickness and slope	1. Dip angle 2. High methane content 3. Tendency to coal self-ignition	1. Unfavorable size of strength and roof compactness 2. Rock burst
	Pillar method	1. Layer thickness over 5 m 2. Rational length of the excavation field to strike and dip	1. Dip angle 2. Physical and mechanical characteristics of the coal seam and surrounding rocks	1. Dip angle 2. High methane content 3. Tendency to coal self-ignition 4. Rock burst	
TECHNOLOGY OF EXCAVATION	Blasting	1. Physical and mechanical characteristics of the coal seam	1. Coal seam thickness	1. Dip angle 2. High methane content 3. Coal seam structure	According to the chosen principle and method of excavation and determining factors, the appropriate excavation technology is selected (alternative combination of two or more technologies)
	Under-cutting	1. Physical and mechanical characteristics of the coal seam	1. Coal seam thickness	1. Coal seam structure	
	Ploughing	1. Physical and mechanical characteristics of the coal seam 2. Layer thickness	1. Physical and mechanical characteristics of floor	1. Coal seam structure	
	Cutting	1. Physical and mechanical characteristics of the coal seam	1. Dip angle 2. Physical and mechanical characteristics of floor	1. Dip angle over 25 2. Coal seam structure	
	Hydro cutting	1. Physical and mechanical characteristics of the coal seam		1. Expresses tendency to coal self-ignition	

### DETERMINATION OF PRODUCTION CAPACITY OF THE UNDERGROUND MINES

The production capacity of an underground coal mine (shaft) is determined by the number of excavation units, the number of preparatory units, the applied technical-technological solutions, and the organizational and safety conditions.

The analytical term for the production capacity of the mine [2]:

$$Q_g = n \cdot Q_o + n_1 \cdot Q_p \quad (\text{tons / year}) \quad (1)$$

where:

- $Q_g$  - the annual production of mines (shaft)
- $Q_o$  - the annual production of excavation (excavations) units
- $Q_p$  - the annual production from the mining rooms
- $n$  - number of excavation units
- $n_1$  - number of preparatory faces

Coal production from preparation faces is calculated by the length of the preparation rooms, the discharge profile of the rooms and the volumetric mass of coal by the expression:

$$Q_p = L \cdot F \cdot \gamma \quad (\text{tons}) \quad (2)$$

where:

- $L$  - length of rooms (m)
- $F$  - discharge profile of the room (m<sup>2</sup>)
- $\gamma$  - volumetric mass of coal (t/m<sup>3</sup>)

The size of  $Q_p$  can be calculated as a shift, daily or annual parameter, depending on the calculation, shift, daily or annual capacity. The calculation of the production capacity of a certain type of excavation should be done in stages, primarily by defining the production cycle of excavation, determining its duration and available time for work during shifts, days or years, determining the structural parameters of excavation and connecting with functional characteristics of excavation equipment [4].

In excavations of any type (pillar, chamber, longwalls), the production capacity and unit costs directly depend on the thickness of the coal seam, and this size is built into the process of selecting technological operations and working phases on excavations. When determining the daily production capacity, care must be taken to be less than the transport capacity - excavation ( $Q_t$ ) and the export capacity of the mine-pit ( $Q_i$ ) in order to take into account the coefficient of irregularity ( $k_n$ ), where the ratio is:

$$k_n Q_d \leq Q_t \leq Q_i \quad (3)$$

With a low level of deposit exploration, the possibility of introducing the new technical-technological solutions is considered from the most unfavorable combination of values of the basic influential natural-geological conditions (especially the tectonic conditions in the deposit, deposit elements, structure and composition of layers and surrounding rocks, physical-mechanical properties of the working environments...). In these cases, the minimum production capacity is predicted from when the analysis of the economic validation of the new solution is started. The issue of minimum and maximum capacity is important for operational technical-technological and economic plans during the exploitation of the deposit [6].

The importance of safety in underground exploitation is especially emphasized, so that every new technical solution must be related to increasing the safety of employees and mining facilities. The capacity of excavation units (excavations) is a quantity that is determined as a function of basic influencing factors and with limitations arising from other subsystems of the mine (shaft). With a satisfactory level of research of natural-geological conditions in the deposit, good knowledge of working characteristics of machines, equipment and devices and established other subsystems, the

capacity of the excavation unit is determined by the duration of the production cycle at the stope and available time during the shift (days) [1]. These two quantities, in the final consequence, synthesize the influence of all the previously mentioned factors on the excavation capacity and can be expressed in the form of an analytical mathematical expression suitable for testing on computers. [4]

After calculating the excavation capacity and preparations, individually and in total for the mine (shaft) it is necessary to check whether it satisfies the economy, and if necessary, adjustments are made to the production capacity, number and schedule of excavations, as well as the dynamics of works. When designing and introducing the new solutions of the excavation system, the so-called "trial work" is applied in practice, the duration of which depends on the complexity of natural-geological conditions in the deposit and the organizational conditions during exploitation.

The main task of the trial work consists the planned technological operations and work phases, organizational synchronization of work operations in the production cycle and obtaining and processing data on all parameters to improve and modify the certain technical-technological and organizational solutions [7]. In other words, the modern solutions for underground coal exploitation require an appropriate professional and scientific approach based on the latest world achievements, starting from the pre-investment analysis phase, through the preparation of project documentation, introduction into practical application and further adjustments [8]. In the literature [1] examples of capacity calculations of different types of excavations (column, chamber, longwall) adapted to the conditions of coal mines in Serbia are given.

## CONCLUSIONS

The production capacity of the mine (shaft) is directly dependent on the applied excavation system and organizational and technological factors of work. As the natural-geological conditions cannot be directly influenced, they try to adapt the selected technical-technological solutions as much as possible to the specific natural-geological conditions. The conditions of exploitation in activated coal deposits in Serbia are relatively complex, with frequent changes in the thickness and elements of coal seams, from deposit to deposit, and often between the excavation fields in the deposits.

The introduction and use of a rational excavation system is preceded by a detailed analysis of the rank of the influence of natural-geological conditions and the procedure of optimization of the main parameters. Production capacity, among other things defines the dynamics and schedule of excavation works in one mine, affects the method and technology of excavation and decisively affects the safety elements and financial performance of the work and operations of the mine. Qualitative and quantitative determination of production capacity is characterized by a number of specifics, and primarily by the predominant influence of natural-geological conditions and organizational factors.

The main directions of development of the system of underground excavation of coal seams are directed towards the introduction and improvement of highly mechanized methods of excavation, with the greatest possible participation of automation, remote control and monitoring. This significantly increases the capacity, achieves the greater effects, increases security and achieves the more favorable and financial results. The calculation of the production capacity of a certain type of excavation should be done in stages, primarily by defining the production cycle of excavation, calculating its duration and available time for work during the shift (days), determining the structural parameters of excavation and connecting with functional characteristics of the excavation machines, equipment and devices.

In excavations of any type (pillar, chamber, longwall) production capacity and unit costs mainly directly depend on the excavation thickness of the coal seam and applied excavation equipment, and especially the number of excavation units, excavation scheme and available time for excavation works are important.

For the conditions of active coal mines in Serbia, the directions of development of the excavation system (methods and technologies) should be directed towards to the mechanization of technological phases and work operations using the mobile multifunctional machines on pillar and pillar and room excavations, considering that these types of excavations will continue to play a leading role. According to the previous knowledge, the rational application of mechanized longwall excavations is limited to the certain excavation fields in the deposits of the Soko and Štavalj mines.

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