

*Professional paper*

## **POSSIBILITY OF APPLYING MECHANIZED COAL MINING IN THE MINE "SOKO", WITH THE COMPARATIVE ADVANTAGES OF PRODUCTION RESULTS AND IMPACT**

## **MOGUĆNOST PRIMENE MEHANIZOVANOG OTKOPAVANJA UGLJA U RUDNIKU "SOKO", UZ KOMPARATIVNE PREDNOSTI PROIZVODNIH REZULTATA I UČINAKA**

**Denić Miodrag<sup>1</sup>, Stojadinović Saša<sup>1</sup>, Vušović Nenad<sup>1</sup>, Kokerić Slobodan<sup>2</sup>,  
Denić Nemanja<sup>1</sup>,**

**Received:** May 16, 2014

**Accepted:** June 06, 2014

**Abstract:** Mining method applied in the RMU "Soko", is repeatedly technologically modified and reached the maximum limit in terms of productivity, level of job performance and safety at work. And all the other methods, which are in the technological process of obtaining coal rely on the technology of drilling-blasting works, in terms of the mine "Soko", can not allow mass production of coal, regarding natural and technical-technological conditions prevailing in Sokobanja coal basin.

Therefore, this paper proposes a possible solution which would enable a significant increase in annual production by applying mechanized coal mining system.

**Key words:** coal production, mechanized coal mining, hydraulic support, combine

**Apstrakt:** Metoda otkopavanja koja se primenjuje u RMU "Soko", tehnološki je više puta modifikovana i dostigla maksimalne granice sa aspekta proizvodnosti, nivoa radnih učinaka i bezbednosti na radu. I sve ostale metode, koje se u tehnološkom postupku dobijanja uglja oslanjaju na tehnologiju bušačko - minerskih radova, u uslovima rudnika "Soko" ne mogu omogućiti masovnu proizvodnju uglja, imajući u vidu prirodne i tehničko-tehnološke uslove koji vladaju u sokobanjskom ugljonosnom basenu.

Zato se u ovom radu predlaže moguće rešenje koje bi mehanizovanim sistemom eksploatacije uglja omogućilo značajno povećanje godišnje proizvodnje.

**Ključne reči:** proizvodnja uglja, mehanizovano otkopavanje, hidraulična podgrada, kombajn

---

<sup>1</sup> University of Belgrade - Technical Faculty in Bor, Vojske Jugoslavije 12, 19210 Bor, Serbia, e-mails: miodrag.denic@yahoo.com; sstojadinovic@tf.bor.ac.rs; nvusovic@tf.bor.ac.rs

<sup>2</sup> PE UCE Resavica, Petra Žalca 2, 35237 Resavica, Serbia, e-mail: kokeric.sb@open.telekom.rs

## 1. INTRODUCTION

In the mine "Soko" applied method is "*Pillar-chamber method with transverse digs, by folding coal roof and coal roof caving*" for many years, and use permit is obtained in the year 1985. Maximum production by this method was achieved in 1987 and amounted to 224,650 tons of coal, but also operating conditions were favorable. Currently, the mine operates with an annual capacity of about 125,000 t. The increase in coal production by applying existing methods is possible to achieve using simultaneous excavation of two independent districts, which would inevitably lead to an increase in the number of workers, hiring of a large number of mechanical and electrical equipment, increasing the cost of maintaining operating efficiency of the equipment, increasing the cost of ventilation holes and reduction in operating performance.

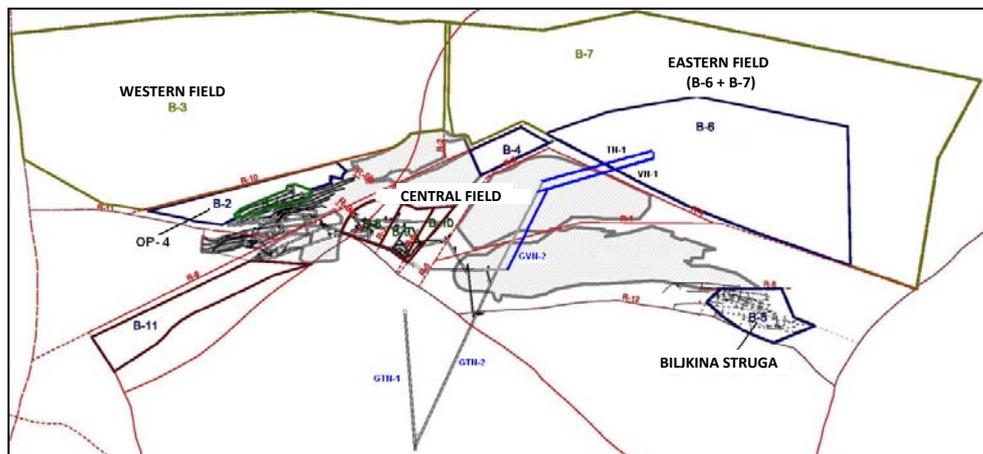
Significant increase in coal production 300,000 - 350,000 tons of coal annually, is possible only by using mechanized mining.

In this paper we show one of the possible methods of mechanized mining with folding roof coal and roof caving that could be applied in terms of deposits "Soko" mine.

## 2. CURRENT MINE CONDITIONS

### 2.1. General basin information

Coal basin "Soko" is part of Sokobanja tertiary coal basin. It is characterized by a complex tectonic structure because within the deposits are identified a larger number of faults of different directions and dimensions, which have divided basin into three tectonic blocks - exploitation fields (Figure 1).



**Figure 1** - Schematic display of tectonic blocks (exploitation fields) of mine "Soko" (RMU "Soko")

- **Central field**, which is defined as the area southern of the fault R-10, limited to the east by fault R-4, fault R-11 to the west and south by paleorelief of Devica mountain;
- **Western field**, is the part of the basin located northwestern of the central field and covers the area western of the fault R-2, northern of the fault R-10, while the northern and western boundaries of the field make lines of calculated reserves of C1 category;
- **Eastern field**, is the part of the deposit located northeastern of the central field and covers the area eastern of the fault R-2, northeastern of the fault R-4, while the northern and eastern boundaries of the field make lines of calculated reserves of C1 category.

## 2.2. Geological reserves and coal quality

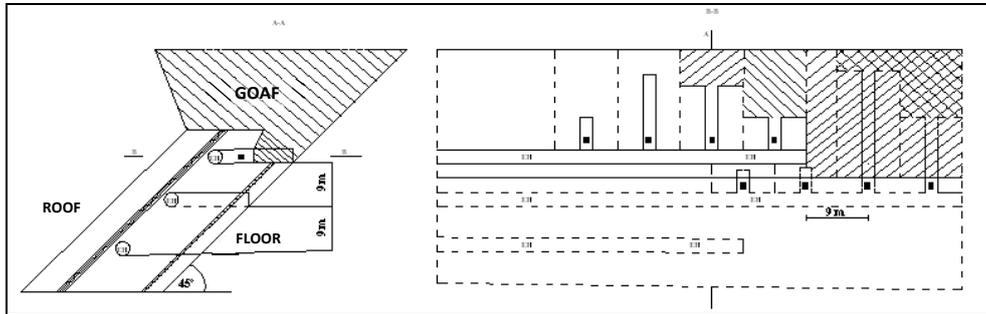
Coal basin "Soko" belongs to the group most promising basins, regarding basin exploration of only 10%. Total geological coal reserves as at 01.10.2012. are shown in the Table 1.

**Table 1** - Geological reserves in "Soko" coal basin

Category	Geological reserves	
	Balance [t]	Off-Balance [t]
A	373,707	2,062,204
B	14,473,971	701,068
C1	41,887,592	
A+B+C1	56,735,270	2,763,272
<b>TOTAL</b>	<b>59,498,542</b>	

## 2.3. Opening model and mining method

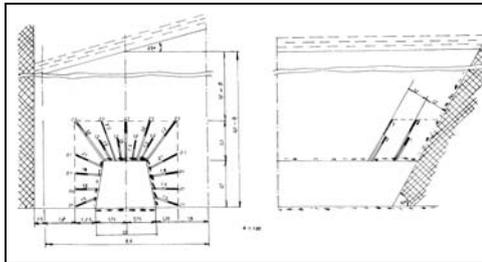
Mine "Soko" applies „*Pillar-chamber method with transverse digs, folding roof coal and roof caving*“. Basic preparation is done by making storey corridors from the opening premises, so that each pair of floors have a direct connection with the main premises of the input and output air stream. Between storey corridors, ventilation uphill are made on each 70 m, establishing flow ventilation. Storey corridors are built by providing and they are located near the marl intercalations of coal seam, horizontally, with circular cross-section of 9.62 m<sup>2</sup>, and supported by a four steel arch support (Figure 2).



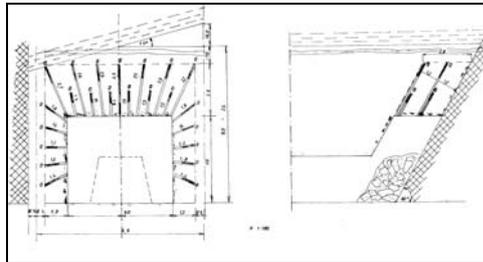
**Figure 2** - The position of storey corridor in the coal layer with location of excavation preparation (RMU "Soko")

Excavation preparation is done by building excavation corridor, from roofing to basement of layer with distance between axis of 9.0 m. These corridors are trapezoidal cross-sectional area of 8 m<sup>2</sup>. Coal excavation is done by technology of drilling-blasting works in two phases overthrow of roof coal, as follows:

- The first phase begins by frontal and side coal mining from the excavation corridors. Fan-drilling holes are being built with length of 1.5 m - 2.7 m. Blasting is done by methane safe explosives and electric detonators. After airing, raw coal is being transported in order to create a working space for the second phase (Figure 3).
- In the second phase remaining coal is knocking down to roofing or grounding excavation steps. Drilling holes are filled with the 0.4 kg methane security explosives and initiation is done without delay interval (Figure 4) (Kokerić et al. 2010).



**Figure 3** - I phase of the overthrow of the roof coal (RMU "Soko")

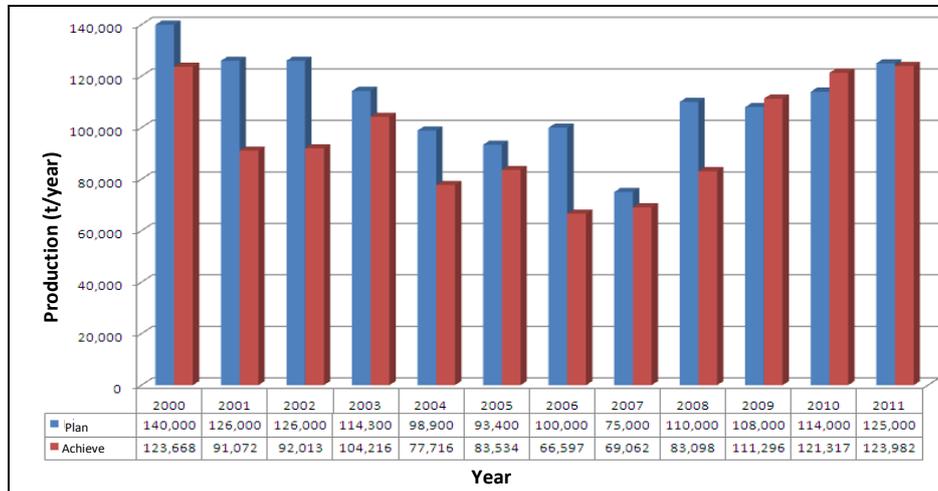


**Figure 4** - II phase of the overthrow of the roof coal (RMU "Soko")

### 2.3.1. Coal production and actual operating results

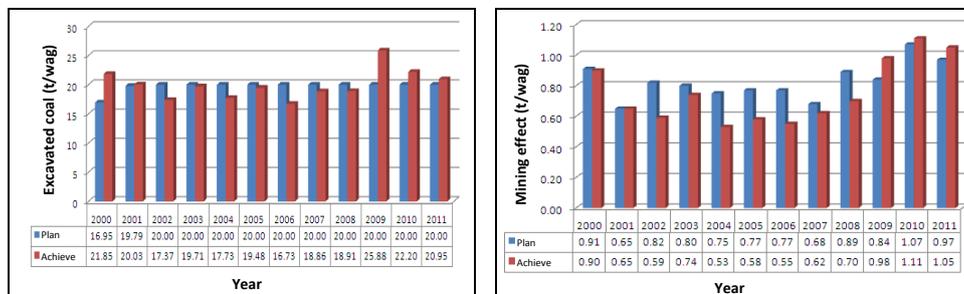
Production of coal in the mine "Soko" in the period between year 2000 and year 2011 took place in the western (OP-1) and the northern wing of the Western field (OP-4). For the given period 1,147,571 tons of coal were produced with an average

annual capacity of 95,631 tons of commercial coal. Planned and achieved production in the mentioned period is shown on the diagram in the Figure 5.



**Figure 5** - Diagram of coal production in mine "Soko" in the period between years 2001 and 2011

The following chart shows that the average performance of existing technology excavated coal is 19.98 t/wag and realized mining effect for the same period is 0.75 t/wag or over 160 tonnes per employee.



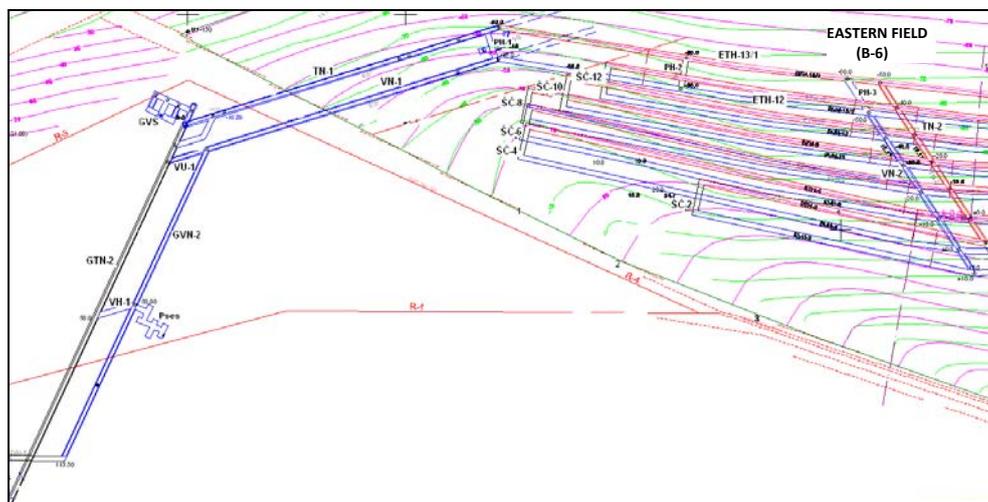
**Figure 6** - Diagram of planned and achieved excavation and performance of mining between years 2001 and 2011

### 3. MECHANIZED MINING IN CONDITIONS OF DEPOSIT IN MINE "SOKO"

Mechanized coal excavation is possible to plan in the part of deposit that spacially belongs to the eastern area of the cave of mine "Soko". Projected opening of mentioned deposit represents a modern way of opening and reservoir development, the so-called "foot wall" system. By design solutions, opening the system performs

inclined road surface (K +397 m) and export pane (K +170 m) to K -44 m, on which is located the first horizon (Figure 7). Projected opening system leaves the possibility of a simple and rational underpinning of the remaining coal reserves in the western area of Sokobanja basin. At this point, the first phase of opening (to K +114 m) is finished by development of mining facilities in length of 2,015 m and 515 m of mining facilities of phase II opening of I horizon (up to K -44 m).

With continuing of works on the development of the II phase of opening I horizon, another 1,475 m of mining facilities should be finished, and after that preparation rooms are preparing to the opening of the first wide forehead excavation with a length of 2,479 m.



**Figure 7** - Layout plan of the opening of the Eastern field with marked broad foreheads western of the TN-2 and VN-2 (steam side)

The opening of the excavation block B-6 of the Eastern field affect the balance geological coal reserves of 11,752,735 tons as the annual production capacity of 300,000 tons enables service life of the mine for the next 30 years. Extending of footwall GTN-2 and GVN-2 opens the excavated block B-7 which affect the remaining balance of geological reserves of the Eastern field in the amount of 14,728,500 tons, thereby extending the life of the mine for another 50 years.

The average mightiness of coal seam in the eastern wing of the central field is 22 m, with a slope towards the north at an angle of 20°, so width (horizontal distance from roofing to flooring coal seam) of wide forehead of 40 m is dimensioned according to that. Due to the small width of the excavation front raises the question of whether to carried out excavation by using a *short blind broad forehead* or *classic wide forehead with conventional flow-through ventilation*, but the security elements defined priority.

### 3.1. Mechanized upbuilding of mining pits and excavation of coal

Mechanized excavation by the system of wide forehead with a flow-through ventilation is based on the development of two storey hall at the same elevation and transverse excavation hall to form excavation. Transport ( $12.7 \text{ m}^2$ ) and ventilation ( $9.62 \text{ m}$ ) corridors are made mechanically (combine machines), of which the transport is supported with steel-arch support with a cons vaulted counter while ventilation is supported bz steel clamp with diameter of 3.5 m, both reinforced with hanging AT support (Denić, 2007). The cross sections of listed facilities fully meet the anticipated mining technology and versatility, as well as the supply and shipment of materials and equipment, transport of coal, the passage of people, service pits, ventilation and other requirements for the normal functioning of the technological process of mining coal.

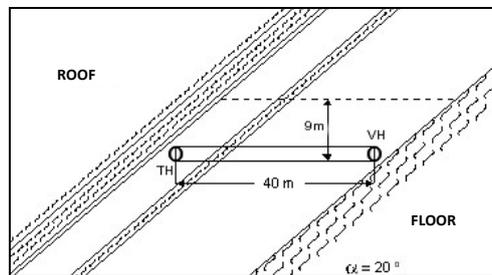


Figure 8 - Position of storey and excavation hallway in the seam

The transport corridor is made by the roof and ventilation by the floor of coal seam. After making the elementary preparation transverse corridor is being built in order to form a mechanized excavation. Transverse corridor is built by coal seam, horizontally by merging transport and ventilation corridors. Mechanized wide forehead with flow-through ventilation in terms of coal mine "Soko" is shown in Figure 9 (Denić, 2007).

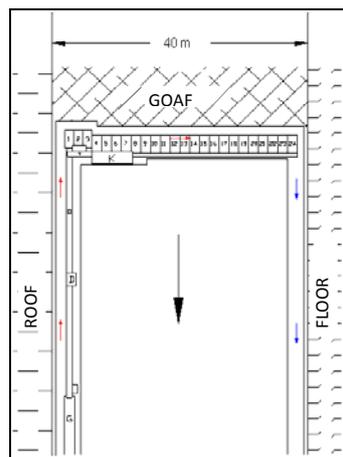
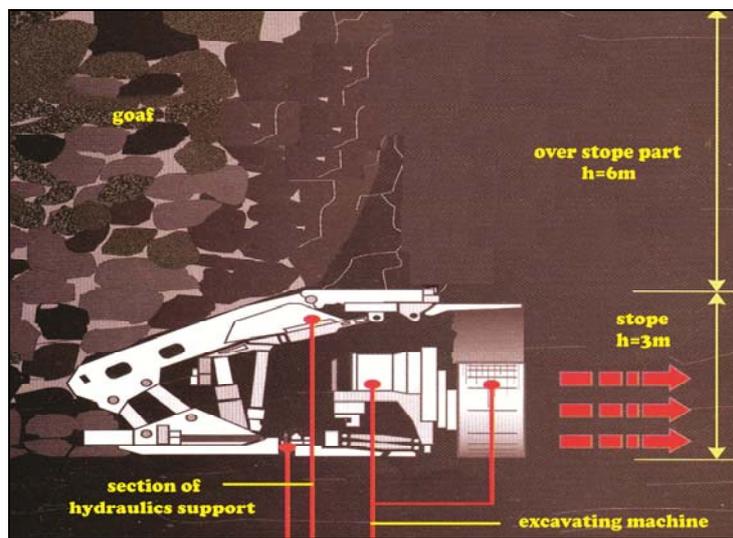


Figure 9 - Wide forehead in terms of coal mine "Soko"

Mechanized excavation is formed so as for supporting transverse hall is used mechanized hydraulic support (MHS) with installed excavated gravel conveyor and excavation machine (combine machine with two cutting rollers), which is moving on the edges of the conveyor.

The process of excavation begins with making appropriate cut from roofing to floor coal seam, by combine with two cutting rollers where would entire subexcavation height of 3.0 m be dug up and loaded on the excavated transporter in one pass of combine and remaining part of the seam, over a section of the wide forehead, would be obtained from upexcavation (Figure 10), which is guided on excavated transporter.



**Figure 10** - Work system of "Top Coal Caving" method on excavation level

Loading of coal on excavation transporter during combine machine is operating performs excavation machine itself, while during demolishing of roofing part of coal seam, shipping is done by lowering the valve in the form of a funnel, which opens-closes the opening in the section shield. Through this hole, over slider, upexcavation coal is routing and loading on excavated gravel transporter. Procedure of felling and loading of roof coal is under the influence of gravity, but that the initial destruction (shredding, crushing) upexcavation part of coal seam section is performed by hydraulic roof support, or force generated in the hydraulic columns support.

### 3.2. Mining capacity

The capacity of the proposed versions of mechanized mining with longwall face ventilation flow excavation, by folding roof coal and roof caving, is obtained on the basis of daily capacity and the number of working days during the excavation.

Daily capacity is calculated by the following equation:

$$Q_d = L \cdot b \cdot h \cdot \gamma \cdot i = 40 \cdot 3 \cdot 9 \cdot 1.25 \cdot 0.812 = 1,080 \text{ t/day} \quad (1)$$

Whereby:

$Q_d$  - capacity of excavation [t/day],

$L$  - forehead excavation width [m],

$b$  - progress of the excavation forehead [m/day],

$h$  - forehead excavation height [m],

$\gamma$  - bulk coal density [ $\text{t/m}^3$ ],

$i$  - utilization (80 - 85%).

Excavation will be done in three production shifts, an average of 25 working days per month, and the remaining five days are available for other productive activities, which annually amounts to 300 working days of the excavation, respectively 300,000 t/y, and total number of employees would be 500.

#### 4. CONCLUSION

Based on the mining-geological conditions in the mine "Soko", international experiences in mining in similar conditions, as well as previous experiences of coal mining in the mine, it is possible to apply the method of mechanized mining.

According to the capacity of coal production of about 300,000 tons per annum, with the width of the excavated panel of 36 m and excavation progress of 3 m/day, it is necessary to excavate length of 900 m of excavated plate for 300 production days in projected year. Since the excavation mine fields in the mine "Soko" are considerably less in length (max 700 m), we must calculate on the time needed to prepare a new excavation panel and relocation of excavation machinery from one floor to another.

Utilization of coal is a problem that appeared in coal mining and in the process of obtaining roofing part, because coal is being crushed into pieces just above the section of hydraulic support, and crushed old work from higher floors is uncontrollably breaking through chunks of coal and discharging directly to the excavated transporter. In such a situation it is possible to place a wire network on the level during the cut of ground works on the floor that would protect penetration of the old work from the higher floors in obtaining upexcavation part of coal or insert composite cement mixture in the form of hydro-cog into old paper behind a section of hydraulic roof support, which would create a certain seam of compact mass above upexcavation part of coal following lower levels and thus prevent the penetration of the old work in the excavation space.

Using this system of coal mining in the mine "Soko" working performance would be much favorable and would be about 600 t/worker compared to the current 160 t.

#### REFERENCES

- [1] DENIĆ, M. (2007) *Analiza uslova za primenu visokoproduktivne otkopne mehanizacije za podzemnu eksploataciju strmih slojeva uglja velike debljine*. (PhD), Univerzitet u Beogradu - Rudarsko-geološki fakultet.

- [2] KOKERIĆ, S. et al. (2010) Possible use of mechanized wide forehead with folding upexcavation coal and roof caving in terms of coal mine RMU "Soko". In: *Proceedings of the III International Symposium "Energetic Mining 2010"*, Banja Junaković, September 2010. Belgrade: University of Belgrade - Faculty of Mining and Geology, pp.368-376.
- [3] RMU "SOKO" (2014) *Dokumentacija tehničkog odeljenja rudnika "Soko"*. Sokobanja: RMU "Soko".