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TECHNOLOGICAL BENEFITS OF RELOCATION AND EXTENSION A CONTINUOUS PART OF THE COAL TRANSPORT SYSTEM[***]

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Abstract

Due to the changing conditions of the working environment or its insufficient knowledge, the coal exploitation takes place with smaller or larger deviations from the designed or planned activities. Depending on which segment of the entire exploitation system the deviation occurred, it will also depend on the extent to which the deviation will affect the profitability and efficiency of exploitation. If major accidents are excluded, the technological process of transport has the greatest impact on the efficiency and economy of exploitation. The newly created situation at the open pit Gacko – Central Field in terms of coal transportation was analyzed in the presented paper. Also, the benefits are presented that arise as a result of reconstruction the combined coal transport system, continuous and discontinuous part. The system reconstruction included the extension of continuous part of transport and relocation the crusher closer to the front of the works, in order to reduce operating costs. On the other hand, discontinuous transport is reduced to the zone where the works are carried out, in order to reduce the operating costs and use the maneuverability of discontinuous equipment. This paper explains the technological-organizational, economic and ecological benefits of reconstruction the coal transport system, for the short and long term.

Keywords: *open pit exploitation, combined transport systems, coal exploitation, benefits*

1 INTRODUCTION

The open pit exploitation of mineral deposits is becoming more and more challenging, especially when it comes to the open pit coal mines. This complexity arises from the deeper deposit, presence of overburden interlayers in the coal seams, and steeper bedding of the seams, all of which together lead to an increase in the overburden coefficient and varying quality [1,2,3]. An important parameter that characterizes the exploitation in these conditions is an increase transport costs with increasing depth of the open pit, while in the case of decreasing depth, these costs decrease [4].

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The application of high-capacity continuous systems reduces the unit costs of transport and thus the total costs of exploitation. In accordance with the different and specific conditions that prevail in the modern open pit mines, very complex machinery is used, which is dimensioned according to the special requirements, in order to be able to respond to the specific working conditions [5]. These systems are structurally and constructively complex and reflect a strong interdependence between elements [6]. They play a key role at the coal open pits where the homogenization process is carried out. This process is aimed to meet the set requirements in terms of minimum costs and environmental impact, as well as ensuring the optimal coal quality by mixing multiple seams with different quality from multiple levels [7].

The case study, presented in this paper, included an analysis of benefits resulting from changing the configuration of the existing DTD system at the open pit Gacko – Central Field. In technological terms, there are clear differences between continuous and discontinuous loading and transport systems. Continuous systems provide a continuous flow of material, while discontinuous systems operate with interruptions in the process. Combined systems, as their name suggests, represent a combination of elements of both groups of systems, with the aim of utilization the potential advantages of both continuous and discontinuous technological solutions [1].

Coal mining in the area of the Gacko coal basin takes place in the area of the open pit Gacko – Central Field in two separate exploitation zones, namely:

- Central Exploitation Zone (CEZ), and
- Roof Exploitation Zone (REZ).

In addition to these two zones, the active execution of works is also being carried out in the area of the Great External Landfill, as well as in the western part of the basin in the area of the former Field B, where the excavated waste is disposed of. From an organizational and functional point of view, carrying out the exploitation is not simple due to the great distance between the work sites. The spatial arrangement of the work sites and problems that arise have already been described by the authors of this paper in earlier publications [8,9].

After the earthquake that occurred in April 2022, the exploitation was first partially, and during 2023, completely moved to the REZ. Due to the very unfavorable situation in the CEZ, primarily the large amounts of overburden that need to be excavated, for a certain period of time the coal exploitation will be realized exclusively in the Roof Exploitation Zone.

1.1 Description of Geology and Working Conditions in the Roof Exploitation Zone

The natural conditions prevailing in the REZ are characterized by a lower coefficient of overburden but also by the complex structural and qualitative characteristics. Spatial arrangement of the seams, more precisely the absence of clear boundaries between the seams and their non-uniformity with characteristically small thickness do not make the process of exploitation simple.

In addition to the structural characteristics of the deposit, the process of exploitation, i.e. provision the necessary quantities of coal of appropriate quality, is influenced by the already mentioned seam thickness and relatively short front of works. The seam thickness in certain parts of the REZ is below the possible level of selection the existing mining equipment. Half of the total number of seams is 0.5 m thick, while about 75% of seams are below 0.9 m [10].

Figure 1 *Overview of working slopes within the REZ with spatial arrangement and seam thickness [11]*

In such working conditions, it is realistic to expect that the exploitation process takes place with losses in production, in the form of losses in both mass and quality of coal. The authors said a little more about losses in the exploitation process in the paper "Analysis of Losses in a Function of Selection the Level of Roof Coal Series - Coal Deposit Gacko" [10]. From the above, it is clear that the entire exploitation process must be carried out selectively [12] and that on this occasion the excavators with a bucket volume of 3 - 6 m^3 should be used as the excavation equipment [13].

2 CONFIGURATION OF THE COAL TRANSPORT SYSTEM AND DESCRIPTION OF TECHNOLOGY

The coal mining system is organized on the principle of a combined system with application the selective mining. According to the existing project documentation, the coal mining is to be realized with the bucket excavators with a bucket volume of up to 6 m^3, and transport of mined coal is to be carried out by trucks with a capacity of 55 t to the crusher. After crushing, coal is transported by the belt conveyors to the secondary crusher, from where it is further delivered either to the landfill or directly to the thermal power plant block.

As a part of the DTD system, there are two crushers SB1515 and SB1315 and 4 conveyors with a belt width of 1200 mm (PTU, TU-1, TU-2, TU-3). Figure 2 shows the spatial arrangement of zones where coal exploitation is planned, network of transport roads and position of facilities within the DTD system for coal transport.

2.1 Description of the problem

The problem that arises in the new situation is that the current position of a crusher and layout of a conveyor is configured as a compromise solution for the balanced or majority exploitation of coal from the Central Exploitation Zone. Due to the lack of equipment and delay in excavating the necessary amounts of overburden, even before the aforementioned earthquake, most of the coal mining was carried out from the REZ. This deviation from the general method of exploitation was reflected in several aspects of exploitation process, in such a way that one problem led to another, and so on until the complete change of work organization, a domino effect.

The reliance of entire production on coal from the REZ required the excavation of significantly larger quantities of coal of lower calorific value. In order to ensure larger quantities of coal, but also due to the lack of trucks with a capacity of 55 t, the entire amount of coal that was mined was transported by trucks with a capacity of 110 t. On the other hand, in order to ensure the efficient selective exploitation of coal, the excavators with a bucket volume of up to 6 m^3 were retained. From the technological side, the excavator-truck system in this configuration is less efficient, primarily due to the long loading time of truck.

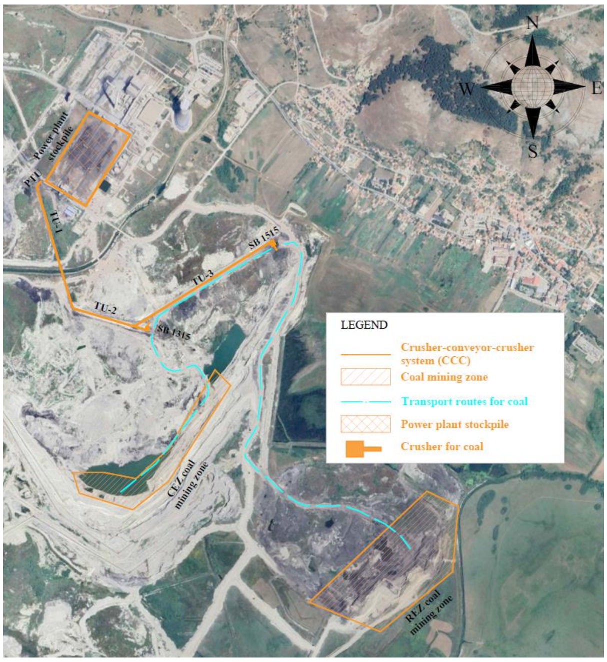

Figure 2 *Spatial arrangement of zones where the coal exploitation is planned, network of transport roads and positions of facilities within the continuous part of coal transport system [14]*

In addition to the impact on excavation technology, a more significant problem arising in the newly created situation is the length of transportation. As it can be seen in Figure 2 currently, the position of a coal crusher is significantly away from the center of mass of the coal mining within the REZ. The length of the route shown in Figure 2 was about 2400 m.

The increase in the transport length affected the increase in normative costs. Which is expected in accordance with the fact that transport is a technological operation that generates the largest part of costs, within operating costs [15, 16]. In addition to the operational costs, it is necessary to hire an additional number of trucks in an organizational sense, both due to the increase in transport lengths and increased need for larger quantities of poor quality coal.

The impact of transport, in addition to the necessary requirements for redistribution the equipment and increase in production costs, also occurs in the environmental aspect. The position of the main part of transport communication from REZ from the crusher position is for the most part at the level of a mining field, which adversely affects the emission of dust and noise to the environment. These impacts are not dramatic and on a larger scale, but they are present; the reduction of which requires the additional attention.

Continuation of the coal exploitation in the future will be realized from the eastern part of the basin, which will result in an inevitable shift of the center of mass to the east. Accordingly, it is realistic to expect that the existing configuration of the DTD system will undergo a certain number of changes.

3 CHANGING THE COAL TRANSPORT SYSTEM

Reconstruction of the DTD system for coal transport is a topic that the authors have dealt with before [17]. Based on that solution, as well as the new findings and plans, the previously defined system was supplemented. Relocation of the coal transport system implies the following technological operations:

- Relocating and changing the configuration of the existing TU-3 conveyor.
- Construction of the route and formation of the new TU-4 conveyor.
- Construction of the route and formation of the new TU-5 conveyor.
- Moving the primary crusher to the REZ.
- Construction of a protective embankment towards the city from excavated materials.

In addition to the work on changing the configuration of the coal transport system, it is possible to reorganize the drainage system with the aim of collecting water from the northern catchment area.

In accordance with the previously stated, Figure 3 shows the conceptual solution for changing the configuration of the DTD system for coal.

Reconstruction of the DTD system included relocation of the existing conveyor TU-3 at the level 936. Introduction of the new conveyors will be realized beyond the reached limits of the open pit mining works. The TU-4 transport route runs in the west-east direction, while the TU-5 transport route runs in the north-south direction. Parallel to the TU-5 conveyor on the western side, there is also a transport road for trucks with a capacity of 110 tons. The plateau of the primary crusher is positioned at level 936 within the REZ.

During the previous period, a major problem in the coal transport and crushing was its wetting during transport on conveyors. In addition to the problems that occurred at the secondary crusher, due to the coal wetting during transport, a problem with a drop in quality was also observed. In order to eliminate the negative effects in the process of reconstruction the DTD system, it is planned to cover all conveyors.

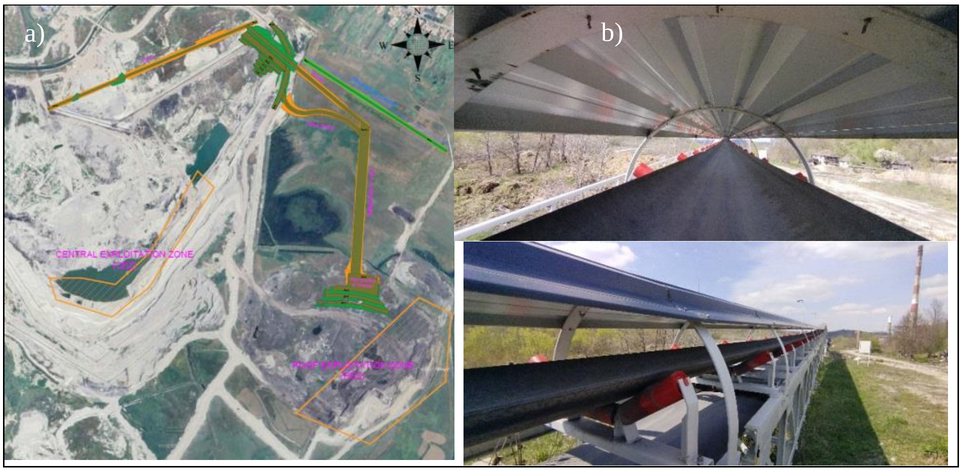

Figure 3 *Arrangement of equipment after reconstruction the DTD system (a) [14] and an example of covering the conveyor (b) [11, 18]*

4 ANALYSIS OF BENEFITS

Reconstruction and upgrading of the DTD system provides technological and organizational benefits for the entire exploitation system. In addition to these advantages of changes in technology or organization, and in addition to improving the working conditions, there is an increase in the economy of the entire exploitation system. For such an undertaking, such as the relocation of the DTD system, it is necessary to allocate certain investment funds. The positive effects of investment do not necessarily manifest as a direct net profit, but their effects can manifest in the form of better use the existing equipment, possibility of more efficient quality management, extension of exploitation time, etc. Also, the realized works can provide benefits in the ecological sense.

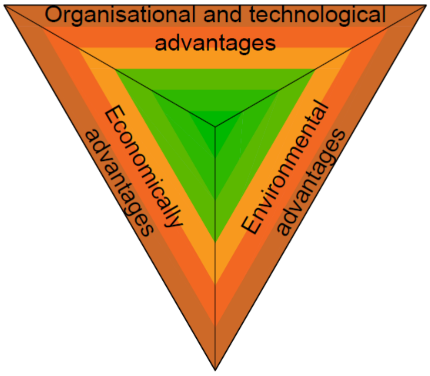

Figure 4 *Triangular scheme of benefits of the system reconstruction benefits*

4.1 Organizational and Technological Benefits

The technological and organizational benefits of reconstruction at the open pit exploitation can be expected primarily in relation to the mentioned disadvantages and aggravating circumstances of the newly created situation. So, it is possible to provide with these works:

- Reduction of transport lengths.
- Re-introduction of the 55 t capacity trucks with excavators with a bucket volume of 6 m^3.
- Increasing the efficiency of coal exploitation technologically and qualitatively.
- Return the trucks with a carrying capacity of 110 t to their original function of transporting overburden transport.

Accordingly, an analysis of a discontinuous part of coal transport from the REZ to the coal crusher before and after the reconstruction of the DTD system for transport with trucks carrying capacity of 110 t (variants V1 and V2) and 55 t (variant V3) was performed. During the analysis in all variants in the excavator-truck system, the excavators with a bucket volume of 6 m^3 were used. The calculation results are shown in Table 1, and the entire analysis was done for the annual coal exploitation capacity for 4 different cases.

Table 1 *Engaged equipment of a discontinuous part of the combined system at the REZ coal mining*

Capacity	Variant					
	V1		V2		V3	
t/year	Excavator	Truck Belaz 75135	Excavator	Truck Belaz 75135	Excavator	Truck Belaz 7555
1,000,000	1	3	1	2	2	3
1,500,000	2	4	2	3	2	4
2,000,000	3	5	2	4	3	5
2,500,000	3	6	3	5	3	6
3,000,000	4	7	**3**	**5**	**4**	**7**

As it can be seen, the two most favorable variants based on the criterion of the number of engaged equipment involve transport over a shorter distance, i.e. from variant solutions with relocation the DTD system. And if, in terms of reserve, it is more favorable to use the trucks with a capacity of 110 t, there is no reason not to use the trucks with a capacity of 55 t. Seen from the point of view of organization the exploitation system, the introduction of trucks with a capacity of 55 t in combination with excavators with a bucket volume of 6 m^3 provides a necessary formation of the system, that is, equipment for coal exploitation. In addition, the trucks with a carrying capacity of 110 t are returned for exclusive operation as a part of the combined system.

4.2 Reorganization Plan of Exploitation

The dynamics of introduction the 55 t trucks can be realized gradually, and Figure 5 shows the Gantt chart of the dynamics of equipment replacement and reorganization of the entire operation.

Ist year - during this period, it is planned to start the process of moving, reorganizing and equipping the DTD system. Also, in addition to the procurement of equipment during this year, it is necessary to start the procedure for procurement the trucks with a capacity of 55 tons.

IInd year - during this period, it is planned that the coal transport system will operate with full or majority exploitation of coal from the REZ. During this period, trucks with a capacity of 110 t are working to transport coal within the REZ, which on average requires a reduction of the truck fleet compared to the first year by 1-2 trucks, depending on capacity, as well as 1 excavator, depending on capacity.

IIIrd year - during this period, it is planned to introduce the 55 t trucks for coal transport, while the 110 t trucks will be fully returned to work with overburden as a part of the combined system.

IVth year - during this period, it is possible to consider reducing the amount of coal from the REZ and starting the exploitation of coal from CEZ as well. This type of exploitation would entail reloading up to 2 trucks with a capacity of 55 t and transferring them to the CEZ.

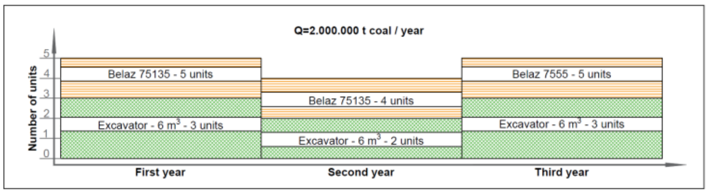

Figure 5 *Gantt chart of work realization for capacity of 2,000,000 tons of coal per year*

4.3 Environmental Benefits

By returning the truck transport to the limits of exploitation zones, the possibility of reducing noise and dust emissions on the surrounding land is achieved. In addition to these benefits, the introduction of the new conveyors, primarily the TU-4 conveyor, whose position is parallel to the urban zone of the municipality of Gacko, it is possible to expect the increased noise generation due to the conveyor operation. In order to reduce noise, the formation of a protective embankment and its greening are planned. Also, in addition to the creation of an embankment that only partially follows the route of the TU-4 transporter, the reconstruction of the transporter implies their covering. In this way, a reduction in the impact of atmospheric precipitation on coal quality is achieved, as well as a reduction in noise and dust emissions.

4.4 Economic Benefits

The economic benefits of changing the configuration of the DTD system are of a long-term nature and primarily relate to the reduction of operational production costs. The fact is that the distance from the location of exploitation to the end consumer is not small and that as exploitation progresses, the distance will grow more and more. The new position of a crusher, as well as introduction the two new conveyors for coal transport, primarily reduce the volume of discontinuous transport, which by its nature is more expensive, but also more suitable for the conditions prevailing inside the open pit. On the other hand, most of the transport has been redirected to the continuous transport, which is more convenient from the economic point of view.

By realization the selective coal exploitation on a larger scale, it is possible to ensure significantly more efficient exploitation, and above all, a longer period of exploitation.

CONCLUSION

The process of surface exploitation THE mineral deposits is a dynamic process that requires periodic progress and displacement of work site (work front). When it is taken into account that the entire process takes place in order to supply consumers such as the thermal power plants, landfills or preparation and processing facilities with excavated mineral raw materials which, as a rule, are fixed and objects of a stationary character, a periodic increase in the length of transport appears as an inevitability. This results in an increase in the costs of entire process, as well as an increase in product price of product delivered to the end users.

The way in which this problem has been solved in practice so far is the introduction of combined transport, i.e. a combination of discontinuous and continuous transport. In this way, the heavy-duty mining trucks are limited to work within the contour of the open pit, while continuous transport is realized from the crusher located on the rim or inside the open pit to the landfill or plant for preparation the mineral raw materials.

In the presented case study that dealt with the newly situation at the open pit Gacko – Central Field, the problem of increased discontinuous transport led to a non-conformity of individual technological operations and equipment operation in the entire coal transport system. From this new situation, it is clear that the existing configuration of the coal transport system must undergo certain changes. The best solution, especially when taking into account that the work front will progress further towards the east, is to extend the continuous part of this system. Applying the existing combined system, along with the extension of its continuous part of transport, the positive elements of both types of transport are used in the most favorable way, while the negative impacts are reduced to a minimum.

For an undertaking like this, it is necessary to set aside two very important resources, namely money and time. The investments are a necessary part of the entire exploitation process, in order to ensure efficient and economical exploitation. From this point of view, time is a significant resource, primarily because the realization of any investment requires the investor to commit the time resources for investment realization. Also, the investment return time is significant because it should be as short as possible. In the specific situation, the investment return is not considered primarily as a net value, but rather as a way that will ensure as soon as possible the most favorable working conditions and increase the efficiency of the coal mining system. Of course, with the provision of these conditions, the economic profit is also expected through reduction the operating costs.

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