Mining of Coal Pillars Using the Drilling Method

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An assessment of possibilities of utilizing other coal mining methods not used yet under conditions of rock and gas outburst hazard in the Ostrava-Karviná Coalfield (henceforth referred to as OKR) in the Czech Republic is one of outputs of the research project "Protection of Employees against Consequences of Rock and Gas Outbursts".

These methods were to supplement a single method that had been in common use by then – longwall mining along the strike, and were to ensure the better recovery of coal reserves [1]. Specifically, it was the case of mining of residual pillars blocking a considerable quantity of coal.

What was chosen was a promising mining method utilising long large diameter boreholes. In the article the experience of application of this mining method abroad as well as under conditions of OKR in seams with a hazard of rock and gas outbursts is presented.

Key words*: Drilling of coal, large diameter boreholes, residual pillars*

Introduction

The objective of the contribution was to familiarize, after the verification of experience from the utilisation of method of drilling abroad, the reader with a proposal for a new method and reasons for necessary modifications of machinery of system based on a variant of "drilling-auger system" - machine BŠK-2DM and a possibility of application of this system in the conditions of Paskov Mine (Czech Republic, OKR).

Principle of Method of Seam Drilling (according to Original Materials of Ukrainian Manufacturers)

In principle, this method is based on the winning of coal from the seam by means of chambers formed by drilling being performed by a special mining (drilling) system. Similarly to the method of classical room-and pillar exploitation, between particular gradually drilled bands (chambers), small safety pillars, from which the coal has not been extracted, are left.

The method was in the country of its origin (Ukraine) [2] intended for the areal mining of coal seams. However, from the point of view of Czech mining industry, it seems to be advantageous to the mining of residual pillars and areas left outside the geometrically regular layout of longwall faces.

By the manufacturer of original system BŠK-2DM constraining conditions for the application of this method were defined in materials provided (in a case of use of original technology). From them, the applicability of this method in the case of use of the mining system followed.

The mining system is, according to available documents provided by the manufacturer, designed for drilling blind chambers of the width of up to 2.1 m and the length of up to 85 m in coal seams of the thickness more than 0.65 m, at the cutting resistance of coal less than 350 kN/m. Boreholes can be directed to a coal pillar to one wall or subsequently also to the other wall of haulage entry, perpendicularly to its axis in the range of seam dip from + 23° to - 15° (Fig. 1). Chambers being drilled are not supported (Fig. 2), merely the mouths of already mined out chambers are closed by dams (round timber sealed with clay).

The finished cross-section of the haulage entry is given by the size of the unit (system), which in the conditions of Ostrava-Karviná Coalfield corresponds minimally to the CH-00-0-12 cross-section for support building. This haulage entry should be horizontal; the gradient of it should be less than ± 8° in the longitudinal axis.

When drilling, the coal is broken by 2 or 3 drill heads (Fig. 1) and is removed by two auger spirals with opposing directions of rotation to the haulage entry. Here, broken coal is taken away by a scraper conveyor. Between the auger spirals (rods) there is a guide mechanism that simultaneously serves the ventilation of face of the chamber, the protection of technological systems and the automatic control of direction of the cutting tool (Fig. 3).

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The blowing ventilation of zone (chamber) being drilled is ensured by means of an electric fan of 500 mm diameter and by means of flexible ventilation tubes, through which fresh air is supplied to the drill unit, where it is connected to the guide mechanism (pipes of 300 mm diameter).

On the haulage entry, whole technology equipment is installed - a hauling track, a power supply device and a hauling cable to the drill unit, an overhead monorail for the supply of drilling modules, a set of drilling tools. The control panel of the whole drilling and mining system is there about 10 m from the chamber being drilled.

Fig. 1. A view of drill heads and a mouth of chamber already drilled in a wall of mine working.

Fig. 2. A view of drill rods and part of driving unit.

Fig. 3. A front view of drill string.

Requirements for Mining and Geological Conditions for the Utilisation of Mining Method of Drilling the Seam

From the operational documentation of original mining system – drill unit, and from the findings of employees of Ostrava-Karviná mines obtained during their business trip to the Dobropolje Mine in the Kharkov area (Ukraine), where the method of drilling is used in a limited degree, some fundamental requirements for the mining and geological conditions for the use of the mining method being evaluated follow. The installation of the drilling system BŠK-2DM requires the following:
steady depositional conditions (above all the dip of the seam) and slight or none tectonic division,
the dip of the seam less than + 23° for upward drilling and less than -15° for pro downward drilling,
the seam thickness more than 0.65 m with a strong immediate roof, with none or only a thin intermediate layer of only claystone rocks.

The findings from the use of mining method of the drilling of coal seam can be summarised into several points as follows:

1. The mining system BŠK-2DM is utilised in the country of origin.
2. The utilisation is, according to the findings from the business trip, only occasional and purely functional.
3. In the documents the manufacturer states a whole series of restraints that limit the installation and utilisation of the system. Generally they are limits characterising the geological conditions, mining and technical conditions under the conditions of Ukraine.
4. The expert opinion of State Committee of Ukraine for Supervision over Labour Protection amends and defines more specifically some operational safety conditions.
5. In the version manufactured by the state enterprise Malyshev Factory in Kharkov, the mining system BŠK-2DM is without fundamental post-modifications, especially for the reason of ensuring the safety of work and operation, unusable in the conditions of OKR.
6. After the adaptation of the system and also of technological processes to the conditions of mining in OKR, the method of mining the coal seam by large diameter borehole drilling can be regarded as possible.

Application of Requirements for the Mining and Geological Conditions for the Utilisation of Mining Method of Drilling the Seam in the Conditions of OKR

The mining system of series BŠK was designed by the Ukrainian designer for the installation in conditions considerably different from those in OKR. Here exist the basic risks that must be specified, assessed and evaluated. What is meant is above all the possible utilisation of the new mining method in the following seams:
classified as threatened by a rockburst hazard,
classified as threatened by a rock and gas outburst hazard,
classified as threatened by hazards of water inrush / increased water inflow,
where the roof/floor consists of sandy varieties of rocks with a high content of quartz (risk of thermal spark).
with the occurrence of intermediate layers.

In all these cases, it is necessary to determine special safety measures always on the basis of expert assessment of the relevant risk.

Geological Conditions

Seam Thickness, Seam Attitude

A. In the case of considered installation of the system in the Czech Republic, in the Karviná partial basin merely the coal seams of Ostrava Formation fulfil the required conditions. Although the dip of layers corresponds to the verified and recommended conditions even in the Saddle Member of Karviná Formation, the thickness of simultaneously mined seams of the lower part of Saddle Member exceeds in order the thickness to which the method has been applied in Ukraine. On one hand, this can be favourable for mining, because when the thickness of the seam is large, irregularities in seam development can be eliminated better; on the other hand, drilling in a thick and often unconsolidated seam may cause a heavy fall of coal and rock in chambers being drilled in any part of them already in the course of drilling.

B. Changes in the seam thickness associated with the bending, shrinkage/pinching out and also splitting of the seam accompanied often with tectonic structures represent points of local stress accumulation. Just here, the measure of probability of occurrence of gas-dynamic event grows, and in the course of performing mining operations in a form of drilling, coal and gas outbursts may occur. These anomalies can, both due to irregularities in seam thickness and due to sudden changes in seam dip, affect negatively also the success of drilling itself, because the rigidity of drill rod does not enable any accommodation to the course of the seam, and a considerable probability of encountering the associated rocks during drilling with all negative consequences exists here.

Tectonic Structures

Areas in the vicinity of tectonic faults where residual pillars usually are there can represent, according to the mechanism of origin and the age of these structures, both points of stress concentration and points of stress release. From the geomechanical point of view, the evaluation of influence of tectonic faults can be carried out not before the overall assessment of stress-deformation state of rock mass for a specific area. In the vicinity of tectonic faults, possible technological problems can be expected that are related to the increased occurrence of planes of discontinuity – accompanying tectonic structures, or water saturation of them, which may cause, as a consequences, a heavy fall in the chamber and a blocking of spiral rod with pushed in coal or associated rocks. In the environment of the seam with a hazard of coal and gas outburst, the increased structural tectonic disturbance of rock mass is together with possible gas accumulation the primary and fundamental precondition for the occurrence of an outburst.

Hydrogeological Conditions

Communication between those parts of the seams with water-filled old workings, water-saturated fracture zones and water-bearing sediments above the Carboniferous relief, in which the method of mining by drilling the chambers is considered, represents a specific risk endangering both the safety of workers and the success of mining operations as a whole. On the other hand, in the case of such parts of the seam the physical and mechanical properties of coal and associated rocks are influenced favourably as for a risk of coal and gas outburst.

Mining Conditions

Dimensions of the Residual Pillar Being Mined, Dimensions of Small Safety Pillars Left in the Seam

Residual pillars that are to be mined by the method of drilling the chambers represent points of stress concentration. Limiting factors are the dimensions of the pillar itself, the depth of occurrence, and the effects of additional stress from the overlying and underlying edges of spaces not worked-out and also from the edges of spaces not worked-out in the seam itself.

In the majority of cases, residual pillars represent the parts of coal seam that cannot be mined by the method of longwall mining along the strike, and represent thus points of increased stress concentration in the coal seam itself and in the surrounding rock mass as well. Dimensions of these pillars then often correspond to the limit state of stress, or are close to these dimensions. The limitation of residual pillars is usually formed by:
old workings,
other mine workings,
tectonic structures, along which the seam shifts by the distance that is greater than the seam thickness,
erosion of the seam.

If any action on residual pillars is performed, including the drilling of the seam using

the new mining method, a certain form of dynamic energy release may occur. A risk of anomalous geomechanical event is here considerable (it is a case similar to the relief of seam stress by boreholes of extreme diameter).

With regard to a possibility of occurrence of a gas-dynamic event, that pillar is hazardous the exploited area of which shows the higher degree of structural-tectonic disturbance, especially in the close proximity to the haulage entry, or in the area of which a decrease in seam thickness due to erosion occurs.

The fundamental criterion for the determination of minimum permissible dimension of coal pillar with reference to a risk of its sudden disturbance by accumulated energy release (risk of dynamic event occurrence) is the compression strength of coal that depends on the rank and the degree of microdisturbance of the seam being mined. It is necessary to state that the compression strength of the seam is considerably variable.

When determining the width of pillars, it is not possible to proceed schematically and to consider a general dimension in advance. When the mining method of drilling is used it is necessary not only to respect certain safety generally, but also to take into account the geological and geotechnical properties of rock mass in the selection of areas.

However, it is completely evident that the only reliable data for the operational determination of width of protective pillars (small interpillars) will be experience from the given operation.

Edges of Spaces Not Worked Out

Edges of spaces not worked out in the overlying seams and in the seam being mined represent points of stress concentration. The influence of additional stress due to these edges of spaces not worked out is determined, for the needs of solutions for outburst prevention, according to the Operating Rules to the Decree of the Czech Mining Office in Prague No. 659/2004 Coll.

For the needs of solving other geomechanical problems in mines without hazard of rockbursts it is possible to utilise, with regard to the fact that there is not any other methodology available, this process that is generally valid for the conditions of Ostrava-Karviná Coalfield.

The additional stress affects adversely (increase) the primary state of stress in associated rocks and in the seam itself. Areas under the influence of additional stress due to the edges of spaces not worked out represent points of increased stress in the rock mass, and thus an increased risk of the occurrence of a geomechanical event of gas-dynamic character.

Mining-Geological Conditions for the Employment of New Mining Method in the Paskov Mine

The area of residual pillars intended for the mining using the new technology is there in the north part of mining claim of the Stařič plant of Paskov Mine, in the mine field 2, in the seam 080 (22b). The seam belongs stratigraphically to the Petřkovice Member of Ostrava Formation. Residual pillars are located along the road 080 7242/1, which is driven in the middle bench of the seam, and are situated SSW and NNE of this road (Supplement No. 1).

Geological Conditions

Depositional Conditions

Residual pillars intended for working out are situated in a relatively steady part of the seam, in the part of a flat anticlinal structure with subhorizontal angles of slope not exceeding 5° [4].

In the course of development and previous mining operations, the multifold splitting of the seam into benches, affecting markedly the morphology of the seam, was verified here. The seam splits into even 4 separate benches. In the NNE direction, where at the distance of about 50 m the worked-out areas of faces 080 200 and 080 201 occur, the upper and the middle benches converge into a single unit. In the layers overlying the middle bench of the seam 080 (22b) an irregular layer of siltstone occurs that gradually pinches out at the line of the above-mentioned connection with the upper bench. Higher, other two benches of the seam 080 (22b) of the thicknesses of 30-50 cm and 10 cm, separated with a layer of sandy siltstone of the thickness of about 3.3 m, follow. In the underlying layers, a 0.5 m thick layer of siltstone with roots is developed; below it there are about a 3.2 m thick layer of siltstone laminated with sandstone and the lower bench of seam 080 (22b) of the thickness of 0.5 m, and further about a 2 m thick layer of sandy soil with roots and a 3.8 m thick layer of siltstone. In the area of connected benches of the seam the total thickness exceeds 100 cm. In the SSW direction, a reduction in the thickness of middle bench appears.

In the areas intended for working out, the depth of occurrence of the seam 080 (22b) below surface moves in the range from 1 140 to 1 150 m.

Tectonic Structures

Structural-tectonic conditions in the wider surroundings of the area of interest are relatively steady – the area of application of new mining technology occurs in the apical part of flat anticlinal structure with the subhorizontal flanks of the angle of inclination less than 5°. In the area concerned, any minor tectonic structure has not been recorded.

The area is located in the underlying layers of the area of west overthrust of NNE-SSW direction and about 15 m amplitude. The shear surface of the overthrust is situated between the seam 080 (22b) and the connected seams 082 (22d) + 084 (22f), which were mined out in the overlying layers earlier.

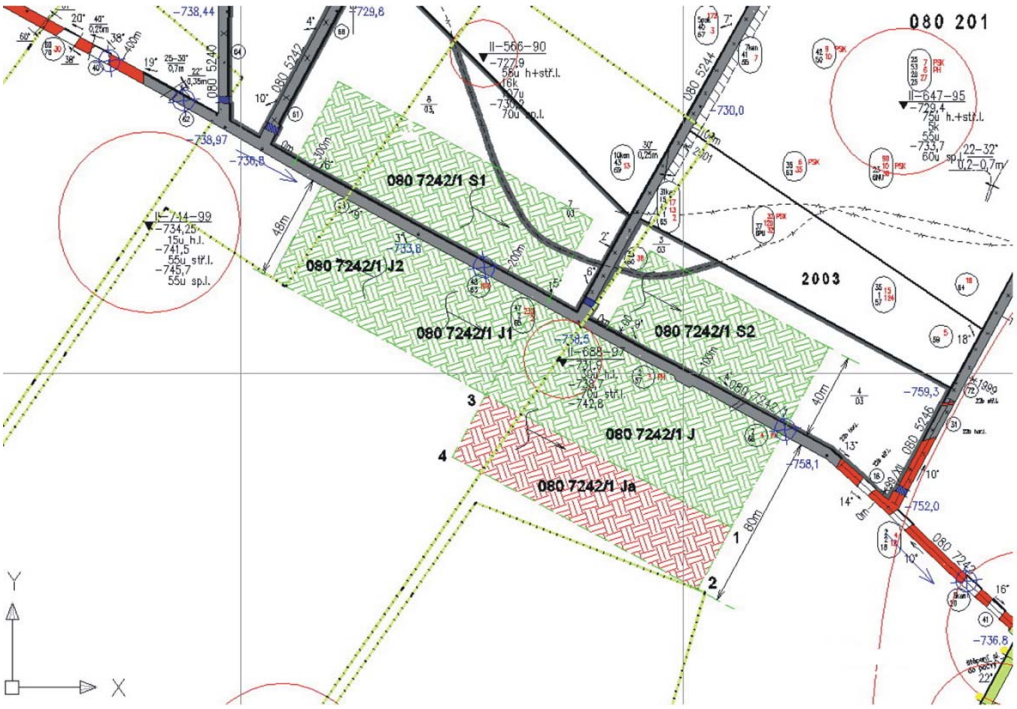
Hydrogeological Conditions

In the area of residual pillars intended for working out, neither water-bearing horizons nor tectonic faults with recorded increased water inflows occur. The risk of approach to the worked-out areas of faces

is eliminated with a sufficient distance between the areas intended for working out and them, including the approach to the closed development workings of these faces.

General Mining Conditions

Dimensions of Residual Pillar Being Mined, Dimensions of Small Safety Pillars Left in the Seam



Supplement No. 1.

The block 1 (080 7242/1 S1)

The first block planned for working out has the length of 130 m along the gateway and the depth of 40 m. As for the areas to be mined, the design width is 1.9 m and the chamber depth is 25 m. The depth of chamber (borehole) corresponds to the length of the borehole performed in the framework of prognosis and prevention of coal and gas outbursts in the block. The width of coal pillars left between individual chambers was determined at 2 m.

The block 2 (080 7242/1 J 2 a 3)

The second block planned for working out has the length of 245 m along the gateway and the depth of 48, or 80 m. In a part planned for working out to the depth of 80 m maximum technical parameters of the mining system will be verified.

The delimitation of the mining blocks is presented in Supplement No. 1.

Edges of Spaces Not Worked Out

The block 1

The first block orientated to NNE of the road 080 7242/1 is in the roof mostly influenced by an overlying face worked out in the area of connection of seams 082 (22d) and 084 (22f) of the thickness of about 1.4 m at the distance of 55 – 60 m. The mining of longwall faces in the roof was performed in the years 2001 and 2002. Mining by using the new mining method is designed to be commenced below the level of edge of worked-out face in the roof in the area of additional stress, and will continue towards ESE into the area protected by the worked-out overlying block.

The block 2 (is operationally divided into parts 080 7242/1 J2 and 080 4272/1 J3)

The second block orientated towards SSW of the road 080 7242/1 is also partially influenced by overlying working as the block 1. Mining by using the new mining method is designed to be commenced in the middle part of the block, and the direction of advance of mining the chambers will be WNW

(part 080 7242/1 J2); the length of chambers will be gradually extended up to the permitted depth limit of 48 m. Mining will be finished in the part of the pillar that is affected by additional stress due to the edge of not worked out part of the seam 082+084.

Another phase of trial operation in the block 2 will be executed in the part 080 7242/1 J3, and the direction of advance of mining the chambers will be of ESE. The length of chambers being mined is determined here, according to the project, at 80 m. The first phase of mining will be carried out under the influence of additional stress due to the edge of worked –out and not worked-out parts of the seams in the roof, and in the next advance of chambers towards ESE merely deeper parts of chambers being mined will be affected like that.

VS-SEAL-625 P1 (P2) – a Modified Mining System BŠK-2DM in Conditions of Paskov Mine

The mining system BŠK-2DM in version supplied by the Ukrainian manufacturer "Malyshev Factory" in Kharkov is unexploitable in conditions of outburst-hazardous mines of OKR owing to not complying with valid Czech legislation – ensuring occupational health and safety and operational safety [3]. For various reasons it was necessary to make constructional modifications in the mining system, especially in the following parts:
the machine itself,
the power unit,
the ventilation system,

with regard to a risk of sudden and uncontrolled increase in methane concentration in the case of occurrence of a rock and gas outburst.

On the basis of requirements specified by the company OKD, JSC, the joint stock company SE-MI Service modified the original system BŠK-2M in accordance with the Czech regulations and produced it under the name VS-SEAL-625 P1 (P2) for the conditions of gassy mines with a hazard of coal and gas outbursts.

General Characteristics of the System

The mining system VS-SEAL-625 P1 (P2), see Fig. 4-6, forms together with a control panel and a so-called "energo-train" a set that is moved, on the floor of haulage entry, by shear by means of a hauling mechanism. The drill unit itself is, in addition to the drilling and driving parts themselves, also equipped with a frame with expanding hydraulic cylinders ensuring both the position of the machine in a mine working and also its anchoring in the walls of haulage entry in the course of drilling itself. The frame of the machine is mounted on slides by means of which it leans against the floor. By the slides it moves by shear along the mine working. For the movement of the unit along the haulage entry of a space being mined, transfer equipment of PZP (PZF) series is used.

The drilling part of the system consists of a driving block of electromotors and gearboxes ensuring the movement of drill string and the rotational movement of spiral drill rods. By means of three drill heads of the diameter of 625 mm, fitted with cutting tools, a chamber is formed in a coal seam.

After the drill heads a gearing part with gearboxes of driving units of drill heads, which forms together with them one whole, and further a section of control, which corrects the direction of drilling, are there.

The gearing part (section) is followed with a transient section, and further with individual drilling sections, i.e. linear sections with inserted supporting drilling sections (each fifth drilling section is used as supporting). An individual linear drilling section is composed of a middle guide part and two drilling spiral rods (augers) of the diameter of 480 mm, by means of which broken material is removed from the space being mined, and by means of which the drill heads are driven. The supporting section contains, in contrast to the linear drilling section, two guide collars beyond; they are fastened together with the middle part and ensure a constant spacing between the spiral drill rods (augers).

The length of individual drill rods forming together with the middle part an "independent drilling section" is 1 540 mm for the type of machine VS-SEAL-625 P1 and 1 040 mm for the version VS-SEAL-625 P2.

The direction of helix is opposite to the direction of spiral rod (auger) rotation; for the removal of coal from the chamber face merely the left rod is used. Thus the right part of the of finished cross-section of the chamber is not filled with any broken material and in the course of all operations it can be utilised for the removal of airs from the face of the mine working – borehole (chamber) being mined. The middle linear guide part is designed for the guide of spiral rods and is equipped with ventilation pipes intended for the supply of required amount of fresh air to the system of separate blowing ventilation of the face and for the supply of water for spraying the face of the borehole in the point of disintegrating (drill heads).

The adding of individual drilling sections, the lowering of them into boreholes, the removing and drawing out of them from the boreholes are ensured by a hoisting device that forms with the drill unit one whole. Individual drilling sections are stored in transport containers (defined by the manufacturer as carriers) hung in cars of overhead monorail ZD-24A. Along the technology track of the overhead monorail, a monorail trolley of the type ŠA-MAN D.01, supplied by the manufacturer of the system together with the carriers, is used for handling them.

Fig. 4. Drilling part of the system at the borehole mouth.

Fig. 5. A control unit.

Fig. 6. A mining system - drilling and driving parts.

Conclusion

In this contribution, basic conditions for the use of new mining method in Ukraine and differences between the Ukrainian conditions and conditions of possible application in the Czech Republic, in the Ostrava-Karviná Coalfield are presented. Reasons for necessary modifications of mining system are given and conditions for possible operation in the Paskov Mine are provided.

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