Study on mining the protective seam with the manless working face in coal and gas outburst mines

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Abstract

In order to solve the problems of backward equipments, low recovery, security issues, high mortality in the coal industry, the technology of manless working face in mine which combined the traditional mining process with the automatic technology is proposed based on the scientized mining, meanwhile, the idea of exploiting the protective seam in the coal seam group of the coal and gas outburst mines with manless working face technology is also proposed so as to liberate other high gas coal seams. Then, making the third coal seam in Shaqu coal mine which is a coal and gas outburst mine as the protective seam was being exploited and carried out the designs which included roadway, equipments selection and mining process. Finally, based on the theoretical analysis and numerical simulation, the gas extraction arrangements is designed, which provides the scientific basis and method for industrial experiment of the third coal seam.

Key words: scientized mining; coal seam group; protective seam; manless working face; gas extraction

1. Introduction

The scientized mining means mining the coal with the highest efficiency on the precondition of safety and environment friendly \cite{1}. China’s coal output is very big, the advanced mining machines must be used in order to adapt to the construction of modern mine, furthermore, the manless working face should also be used in some difficult conditions such as thin coal seam or coal and gas outburst seam. Although the mining technology develops rapidly, the overall level is still relatively backward. In order to solve this problem, change the present situation and keep the sustainable development of coal resources \cite{2}, the author proposes that the protective seam is mined with the manless working face in the coal and gas outburst mines. Then other high-gas coal seams can be liberated and the gas concentration can also be decreased, so there will be a safe condition for mining. Finally, the safe and high efficient green mining will be achieved \cite{3}.

2. Mining the protective seam in high outburst mines

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doi:10.1016/j.proeps.2009.09.037
The coal seam group is one character of the high gas mining area in China and the permeability of coal seam is very low \[4\]. Therefore, gas is the primary factor which prevents this kind of mines from safety and high efficiency. The protective seam mining is widely used in these high outburst mines in China so as to solve this problem. In addition, this is the most scientific method to prevent the regional gas outburst under the condition of mining the coal seam group in high outburst mines \[5, 6\].

When there is a coal seam group in the gas outburst mine, the no-outburst seam or little-outburst seam will be firstly exploited, and this kind of coal seam is called the protective seam. The original equilibrium state of stress will be broken after the protective seam is exploited. Besides, with the development of roof and floor, the strata stress will be redistributed. The roof strata can be divided into caving zone, fractured zone, and bending zone \[7\], the floor strata will generate floor heave and fractures \[8\]. The fractures contain bedding joint and cross-fracture, the degree of the fracture development of the floor is in inverse proportion to the spacing of layers. The methods of gas extraction can be classified as short distance, medium distance and long distance through the relative spacing of layers which is based on the concrete geological conditions of the coal mines \[9\], which provides a theoretical guidance to the gas control of coal seam group.

The practice of mining the protective seam shows that the gas permeability of the upper outburst-relieved seam increases 1000-3000 times, while that of the lower outburst-relieved seam increases about 1000 times. This provides a good chance for gas extraction. So the effect of the increased gas permeability should be fully utilized to extract the gas by arranging kinds of drillings or roadways which not only ensures the safety of mines but also guarantees the extracted green and efficient gas energy for industry. Then the simultaneous extraction of coal and gas can be realized. The concrete methods are as follows:

1. Extracting the gas by ground surface drilling. This method is applied successfully in America \[10\], besides, Huainan, Huaibei, and Tiefa mining bureaus also made some tests or applications \[11\]. Although they have got some effect, the stability of the drillings are not very well so that they are broken before the expected life for the different geological conditions between China and America and the influence of the movement of the overlying strata.

2. Arranging some drillings and roadways in the coal seam or strata to extract the gas which is the main method widely used in solving the gas outburst problem.

3. Analysis of the feasibility and application in manless working face

3.1. Analysis of the feasibility

The modern manless working face is proposed with the principle of scientized mining and comprehensive utilization of coal resources \[12\]. Based on the concrete conditions of China, we analyze the feasibility of manless working face:

The gas emission of the thick and medium-thickness coal seam is more thinner than coal seam, so the thin coal seam is the first choice as protective seam. At present, although the mining degree of channization and automation in thick and medium-thickness coal seam is relatively high, but in thin coal seam is relatively backward. Blasting mining is the main method of mining the thin coal seam, on the one hand, the mining production rate is low and the partial coal resource is lost \[13\]. On the other hand, the working environment is bad and the labor intensity is big. Considering these unfavorable factors, many coal mines give up exploiting the thin coal seams. This action not only wastes the coal resources seriously but also shortens the service life of the mines, meanwhile, it also restricts the development of the protective seam in the coal seam group of the coal and gas outburst mines. So the urgent affair in mining field is to develop the high yield and high efficiency mining technology.

Based on the system model of the manless working face, we make some integrated innovations on the modern technology and analyze the needed technology of every subsystem such as self-positioning and automatic navigation technology of the shearer, automatic vertical steering technology of the shearer, automatic recognition technology between coal and strata, electro-hydraulic control technology of the hydraulic support, automatic traction technology of the scraper conveyor, two-way communication technology of high-speed in the underground, component based coalmine software as well as the model technology, database technology and multi-sensor technology.

After being combined with these technologies, the manless working face technology can greatly improve the mining rate and promote the security.
Coal is the main energy resource in China, the healthy development of the coal industry is related to the energy security and economic sustainable development of China. The coal is non-renewable resource and the service life of the mine is certain. If the thin coal seam can be exploited through the existing production system, the recoverable reserves will be increased, and then the economic benefit will also be increased.

At present, gas explosion has the highest proportion in all kinds of the coal mine accidents in China. There were 182 coal mine accidents in 2008, the death toll was 778. So the preventing of gas accidents shoulders heavy responsibilities.

3.2. Application

Based on the scientific mining, exploiting the protective seam with manless working face is proposed combined with these analyses in coal seam group of the coal and gas outburst mines. After the gas in the coal seam group is released, it can be extracted by the reasonable drillings. It is a win-win method, not only will the frequent gas overrun, frequent gas accidents and the limitation of scale be solved, but also the problems of great difficulty in mining and low mining rate. Furthermore, the green mining of coal resources can be realized by simultaneous extraction of coal and gas.

4. Example of mining designs in manless working face

4.1. Condition of text area

The Shaqu coal mine of the HUAJIN coking-coal company is a coal and gas outburst mine. The absolute outflow of gas is 344.43 m$^3$/min and the relative outflow of gas is 61.8 m$^3$/t. It is a short distance coal seam group and the minable seams are the second, third, forth and fifth coal seam (Fig.1).

Fig. 1. Columnar section of coal and strata seam

The article 193 of coal mine safety regulation prescribes that the protective seam should be exploited preferentially when mining the coal seam group in coal and gas outburst mine. The article 198 prescribes that the gas of liberated seams should be extracted when mining the protective seam $^{[14]}$. So the Shaqu coal mine constitutes
the regional gas government which the third coal seam is mined to liberate the second and third coal seam in order to guarantee the safety and efficient mining.

4.2. Design of the working face

The 13301 working face of Shaqu coal mine is chosen as the experimental area where U-type ventilation is designed in line with reducing the amount of roadway as well as decreasing the gas concentration. In order to extract the gas of 13301 working face, the inclined dense drillings are bored in the return airway by the ADR 250 High-Efficiency drilling rig (Fig.2).

The aperture of the drilling rig is 250 mm and it’s very rare home and broad. The big aperture which is beneficial to extract the gas can greatly improve the extraction rate. The length of the working face is 150 m and the length of the drilling is 140 m, arranging the drilling every 6 m in the direction of tendency and all the drillings are parallel. The distance between open-off cut and the first drilling is 15 m and the last one is at the stopping line, so there are altogether 160 drillings. Using the spiral-welded steel pipe as the main pipe which is laid along the floor and UPVC as the branch pipe which is suspended from the roof, the size of the former is DN820mm×12mm and the latter is D225mm×10mm. The connection model is flange joint.

The shape of the roadway is rectangle using the combined support of anchor, metal net and W-type steel band to support the roadway. Both the width of the conveyance roadway and return airway is 4.5 m, the height of the roadway is 2.8 m.

4.3. Selection of the equipments in the working face

Choice of shearer

Fully automatic mining system of the plough is an effective way to realize high production and efficient\textsuperscript{[15]}. The features of little depth-web, fast advance speed and high adaptability make it the first choice in mining the thin coal seam. In order to realize the high production, high efficient and high automation, the GH9-34ve/4.7 plough of the DBT Company is selected combined with the concrete conditions in Shaqu coalmine. The rated power of this plough is 160/315 kW and the production capacity is 900 t/h. It can meet the requirement of high production and high efficient.

Choice of hydraulic support

Following the principle of reliable system and the priority of domestic equipment, we select the Germany PM4 control unit combined with the domestic hydraulic support. The concrete type is ZY4800/6.5/16.5D of the middle hydraulic support and ZZ5800/16/30 of the terminal hydraulic support.

Choice of scraper conveyor
The current proportion between the scraper conveyor and shearer is 1.2~1.4:1. In order to exert the capacity of the scraper conveyor, we select the PF2.30/732 scraper conveyor.

The capacity of the fully mechanized mining equipments should be based on the capacity of the shearer. Meanwhile, the principles of the speed-matching, connection-matching, etc. should also be taken into consideration. Then the main equipments of the working face can be determined (Table 1).

<table>
<thead>
<tr>
<th>Equipment name</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plough</td>
<td>GH9-34ve/4.7</td>
</tr>
<tr>
<td>scraper conveyor</td>
<td>PF2.30/732</td>
</tr>
<tr>
<td>Middle hydraulic support</td>
<td>ZY4800/6.5/16.5D</td>
</tr>
<tr>
<td>Terminal hydraulic support</td>
<td>ZZ5800/16/30</td>
</tr>
<tr>
<td>Transfer machine</td>
<td>SZZ764/132</td>
</tr>
<tr>
<td>Crusher</td>
<td>PEm1000×650</td>
</tr>
<tr>
<td>Belt conveyor</td>
<td>SSJ1200/m</td>
</tr>
</tbody>
</table>

### 4.4. Mining technology

By means of the combined auto-control shearer and hydraulic support, the automatic coal cutting, automatic advancing support and the linkage of the scraper conveyor can be realized, meanwhile, using the centralized control and sequential start-stop to realize the automatic control (Fig.3).

![Fig. 3. Technological process](image)

### 4.5. Design of gas extraction

#### 4.5.1. Numerical simulation

The numerical simulation software UDEC is adopted to provide the theoretical basis for the gas extraction so that the gas outburst of the first mining seam and the contiguous seams can be governed well. Taking the strike section of the 13301 working face as field model, then, the numerical model can be built, length of tendency × length of inclination=250×55 m, the elevation of the third coal seam is 450 m. The left hand, right hand and lower boundaries of the model are displacement boundary. The left and right boundaries constrain the displacement in x-direction and the lower boundary constrains the displacement in y-direction (Fig.4).
The change law of the mining influence, height of fractured zone in the roof and floor and the change law of fractured zone with the advancing of working face are simulated in this numerical simulation. The results are as follows:

When the advance distance is 40 m (Fig.5), basic roof begins to collapse. The height of the caving zone is about 6 m and the strata near basic roof are destroyed by tension. The vertical fracture and interlayer fracture are generated in the overlying strata and the height of breaking though fracture is about 10 m. There is some deformation in floor of the goaf, which can be seen from the displacement curve of the floor that the maximum compression deformation is 7 m around the lateral of cutting hole and 7 m around the front of the working face. The maximum floor heave deformation is 5 m around the medial of the cutting hole and 5 m around the rear of the goaf. The maximum deformation is 30 mm. When the advance distance is 60 m (Fig.6), the overlying strata and floor strata are destroyed by the interaction of principal stress and shear stress, moreover, the vertical fracture and interlayer fracture develop constantly. With the advancement of the working face, interlayer fracture is the main fracture above the basic roof of the goaf. The main range of vertical fracture is 5 m away from the roof and floor.

4.5.2. Design of the gas extraction arrangement

It can be obtained from the theoretical analysis and numerical simulation that the second coal seam is in the fractured zone of the third coal seam and the forth coal seam is in the deformation zone of the third coal seam. So the gas can be largely extracted after arranging some drillings in the fractured zone of the roof and deformation zone of the floor.

The DDR1200 directional drilling rig which introduced by the Shaqu coal mine can be controlled artificially to drill along the roof or floor at some angle. The aperture is 170 mm and the drilling length is 1200 m. The 13301 working face is selected as the experimental area and the concrete schemes are:

Four drillings were born when they reached the forth coal seam, then, boring in the forth coal seam. These drillings can extract the pressure relief gas of forth coal seam and the gas between the third and the forth coal seam.
Four drillings were born when they reached the upside of the second coal seam and the vertical distance between the second coal seam and the drillings is 3 m, then, bore along the direction of parallel to second coal seam. So the second coal seam can be liberated. The profile drawing of the drillings is shown in Fig.7.

So the coal seam group can be liberated and the problem of gas outburst can also be well solved.

Fig. 7. Schematic diagram of profile in 13301

5. Conclusions

The problems of coal mining in China are researched and the manless working face is proposed, which is based on the automatic conditions of fully mechanized mining coal face ,It is an important way to realize the sustainable development of coal industry.

The idea of mining the protective seam with the manless working face in the coal seam group of the coal and gas outburst mines is proposed. Not only the problem of hard-mining in coal and gas outburst mines will be solved but also the problem of hard-mining in thin coal seam can be solved.

Working face design, equipments selection and mining technology design are carried out to the third coal seam based on the concrete conditions of the Shaqu coal mine.

Feasibility of making the third coal seam as protective seam is verified based on the theoretical analysis and numerical simulation and it provides a new thought to the safe and high efficient coal mining.

Acknowledgements

Financial support for this work, provided by the National Natural Science Foundation of China, is gratefully acknowledged.

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