Study on Gas Comprehensive Control Technology in Steep and Extra Thick Coal Seam

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Abstract. In order to improve the gas drainage amount and drainage rate of steeply inclined and extra thick coal seam and realize the safe and efficient mining of coal mine, the distribution and evolution law of surrounding rock stress field and fracture field of horizontal slicing mining face in steeply inclined coal seam were revealed by using numerical simulation method, and the gas flow process and law from lower pressure relief gas to slicing mining face were analyzed. The comprehensive control measures of combination of pressure relief gas interception and drainage and buried pipe drainage in the goaf of this layer have realized the effective gas control of the mining face in the mine production process. The research results play a typical demonstration role for the comprehensive control of rock burst and gas in steep and extra thick coal seam in Xinjiang and even in the whole country, and have promotion significance.

1. Preface

The horizontal sublevel fully mechanized top coal caving method in steeply inclined and extra thick coal seam is one of the important achievements in the technical reform of fully mechanized top coal caving mining in steeply inclined and extra thick coal seam. To some extent, it realizes the high production and high efficiency in mining steeply inclined and extra thick coal seam. Compared with the general mining method in steeply inclined coal seam, it has the advantages of high production capacity, low tunneling rate, high labor productivity and low mining cost. The law and characteristics of gas emission in steeply inclined coal seam are different from those in inclined and gently inclined coal seam, which shows that the amount of gas emission in goaf is large[1-4]. At present, there is little research on gas emission law and gas disaster prevention technology of horizontal slicing mining face in steeply inclined and extra thick coal seam in China, and there is also a lack of relevant standards and basis for gas emission prediction of this kind of working face[5-7].

In order to control the gas disaster more effectively and reduce the influence of gas disaster on safety production, it is necessary to analyze the gas occurrence law, gas emission law, gas emission characteristics and influencing factors of gas emission in steeply inclined and extra thick coal seam. Establish the gas drainage technology system and gas drainage effect evaluation system suitable for mine conditions, and support the corresponding gas disaster management system to ensure the gas drainage measures in place[8-10].

The coal seam in Wudong coal mine has the characteristics of steeply inclined and extra thick coal seam, rock burst, large amount of gas emission, rich in hydrogen sulfide and easy spontaneous...
combustion. The dip angle of coal seam in north area is 43-46° and the gas concentration of coal seam is more than 90%. In order to improve the gas drainage amount and drainage rate of steep and extra thick coal seam, and realize the safe and efficient mining of coal mine, this paper takes the gas of Wudong coal mine of Shenxin energy company as the research background, and uses the numerical simulation method to reveal the distribution and evolution law of surrounding rock stress field and fracture field of horizontal slicing mining face in steep coal seam, and analyzes the direction of pressure relief gas from the lower part of coal seam mining to slicing mining. Based on the gas flow process of working face, the main influencing factors of gas emission in horizontal slicing mining face of steep coal seam are determined, and the comprehensive control measures combining the regional pressure relief gas interception and drainage with the buried pipe drainage in the goaf of this slicing are formulated and implemented, so as to realize the effective gas control of the mining face in the mine production process.

2. Main technical principles
Gas control implements the general idea of "regional prevention and control, drainage before mining, and drainage up to standard", adheres to the principle of regional measures first and local measures as supplement, and in view of the actual situation of slicing mining and unprotected seam mining in steep inclined extra thick coal seam of Wudong coal mine, the main technical means are the following slicing pressure relief gas interception and drainage and the pre drainage of coal seam gas by long boreholes along the seam. Solve the problem of gas disaster, and finally achieve the balance of "drainage, drilling, mining and excavation".

3. Analysis of numerical simulation results
3.1. Distribution of stress field and fracture field in horizontal slicing mining of steeply inclined coal seam
According to the numerical simulation results, it can be seen that:
- After horizontal slicing mining in steeply inclined coal seam, obvious original rock stress area, stress concentration area, pressure relief area and stress recovery area are formed in the lower coal body along the strike; in the inclined section of coal seam, stress concentration will be formed in the lower part of slicing near the roof side, and obvious pressure relief phenomenon will be produced near the floor side. According to the distribution of mining stress field and fracture field, the coal and rock mass are divided into three areas: normal stress fracture unchanged area, stress concentration fracture closed area and pressure relief fracture developed area. The pressure relief fracture developed area is the main area for mine gas drainage.

- After the upper slicing mining, the lower coal body has obvious pressure relief, the pressure relief range near the coal seam floor side is high, and the pressure relief degree near the coal seam roof side is low; affected by the upper slicing mining, the pressure relief depth of the lower coal body near the roof side is about 5m, and the full pressure relief depth in the middle of the coal body is about 5m. When the mining length is about 15m, the mining influence depth is about 25m, and the full pressure relief depth near the floor side is about 25m, and the mining influence depth is about 35m; when the mining length is about 50m, the pressure relief influence depth no longer increases with the increase of the working face length, but the pressure relief area increases along the coal seam strike.

The results of numerical simulation reveal the distribution and evolution law of surrounding rock stress field and fracture field of horizontal slicing mining face in steeply inclined coal seam, and provide theoretical support for the layout of pressure relief and extraction boreholes in horizontal slicing mining face in steeply inclined coal seam.

3.2. Gas occurrence and flow law of mining coal
According to the numerical simulation results, it can be seen that:
In the process of slicing mining, the permeability evolution of the lower pressure relief coal undergoes the evolution process of initial value $\rightarrow$ small decline $\rightarrow$ large increase $\rightarrow$ stability $\rightarrow$ later decline. Different from the mining slicing distance, the permeability coefficient of the coal changes differently, showing the law of decreasing with the increase of the distance. Gas flow in pressure relief coal is a process of desorption diffusion seepage, and permeability is the key factor affecting gas drainage. Stress change has a significant impact on coal permeability.

Under the negative pressure of 20kPa and 180 days, the reasonable spacing of drainage boreholes is 6 m. Through numerical analysis, the lower pressure relief coal body can be divided into pressure stable area, pressure reducing area and pressure increasing area according to the gas distribution without gas drainage.

The gas concentration of horizontal slicing mining face in steeply inclined coal seam increases gradually along the length of the working face. The gas concentration along the section of the working face near the coal wall and near the goaf is larger, and the gas concentration in the lower part of the vertical direction is greater than that in the middle part.

3.3. Gas emission law of slicing mining face in steep seam

The measured gas content of 45# coal seam at +500m level in Wudong coal mine is 6.43m$^3$/t, and the gas content gradually increases with the increase of coal seam buried depth, which basically conforms to the general law of coal seam gas occurrence. Through the analysis of gas emission law of working face, it is concluded that the gas emission of goaf in the West Wing working face of Wudong +575m level coal seam accounts for 80.75% $\sim$ 92.59% of the gas emission of working face. The model is established to predict the gas emission of $+575$m level 45 # West working face after pre drainage. The prediction results show that the pressure relief gas emission of the lower coal body of the mining layer accounts for 37.03% of the gas emission of the whole working face, the gas emission of the adjacent layer accounts for 2.72%, the gas emission of this layer accounts for 47.22%, and the gas emission of the upper goaf accounts for 12.98%. The composition of gas emission is shown in Table 1.

Through the test of taking coal core to measure coal seam gas content in the lower part of the working face before and after mining, it is concluded that the mining influence depth is about 30m, and the mining influence degree near the coal seam floor side is greater than that near the coal seam roof side.

| Name             | Emission(m$^3$/t) | Proportion(%) |
|------------------|-------------------|---------------|
| Mining slicing   | 2.95              | 47.27         |
| Adjacent layer   | 0.17              | 2.72          |
| Lower coal body  | 2.31              | 37.03         |
| Upper old goaf   | 0.81              | 12.98         |
| total            | 6.24              | 100           |

It is clear that after the gas pre drainage measures are taken in the working face, the key work of gas control in the mining process of the working face is to carry out the pressure relief gas interception and drainage of the lower coal body and the gob buried pipe drainage. The main sources and seven parts of gas emission in horizontal slicing mining face of steep coal seam are determined, which are pressure relief gas emission from coal seam in front of slicing mining face, gas emission from caving coal body, gas emission from top coal in upper part of working face, pressure relief gas emission from coal seam in lower part of working face, gas emission from goaf, gas emission from adjacent layer and gas emission from goaf.
4. Gas control technology and effect analysis of slicing mining in steep seam

4.1. Gas control technology of slicing mining in steep seam

According to the gas emission law and distribution of working face in Wudong coal mine, the gas drainage measures of buried pipe in goaf and pressure relief in lower layer are adopted to control the gas in the mining process.

4.1.1. Gas drainage by buried pipe in Goaf

The first buried pipe is laid in the return air roadway, the length of the buried pipe is about 30 m, the front end of the buried pipe is closed, and four holes with a diameter of 10 mm are drilled along the pipe wall every 0.1 m in the 1 m long pipe section at the front end, so as to form the buried pipe mouth for gas drainage. When the buried pipe is buried 20 m, the second buried pipe shall be laid. When the second buried pipe is buried about 5 m, the second buried pipe shall be connected to the gas drainage branch pipe, and the first buried pipe shall be removed and the interface shall be closed. In this way, the gas in the goaf can be drained by two times of buried pipe circulation, and the schematic diagram of three zones of gas in the goaf of the working face is shown in Figure 1.

![Figure 1 Three gas zones in goaf of working face](image1)

4.1.2. Pressure relief and interception pumping

According to the experimental research, affected by mining, the lower coal body has pressure relief effect in the middle vertical depth of about 15m, and has pressure relief effect in the vertical depth of about 25m near the floor side. Through the analysis of gas emission law and emission source, the pressure relief gas emission of the lower coal body accounts for about 45% of the gas emission of the whole working face, and the lower pressure relief tile is implemented. Gas interception and drainage is the key technology to solve the problem of lower pressure relief gas emission. The special gas drainage roadway is constructed at the level of +500m in the lower part of the mining layer, and fan-shaped boreholes are arranged in the roadway. The borehole diameter is 113mm, the length of boreholes is 150m, the spacing between boreholes is 90m, and the length of borehole overlap area is 60m. The variation curve of gas concentration in pressure relief drainage borehole is shown in Figure 2.

![Figure 2 Gas concentration curve of pressure relief drainage borehole](image2)
4.2. Analysis of gas control effect

4.2.1. Analysis on the effect of pipe buried extraction in goaf
According to the depth of buried pipe in goaf, the gas concentration in the upper corner can be divided into the area with rapid decrease of gas concentration, the area with 1~35m buried pipe depth, the area with stable gas concentration in the upper corner, the buried pipe depth is 35~100m, and the area with increased gas concentration in the upper corner, the buried pipe depth is more than 100m. Based on the comprehensive analysis of the drainage flow of the buried pipe in the goaf of the working face, it is concluded that the reasonable depth of the buried pipe in the goaf of the 45 # coal seam working face is 10 ~ 35m. The distribution of gas concentration in the upper corner of buried pipe drainage is shown in Figure 3.

![Figure 3 Gas concentration distribution in upper corner of buried pipe drainage](image)

4.2.2. Analysis on the effect of pressure relief and interception
The gas concentration and gas flow decrease gradually with the increase of extraction time before the pressure relief and drainage borehole. The gas drainage parameters decrease obviously. When the mining face enters the pressure relief area, the gas drainage parameters increase rapidly. By observing the gas concentration changes in the borehole, the gas concentration in the borehole increases from 26.4% to the maximum value 68.5%, the gas flow increased from 0.16 m³/min to the maximum of 0.67 m³/min, and the average gas flow increased by 4.4 times. The gas concentration and flow change curve of pressure relief drainage borehole is shown in Figure 4.

![Figure 4 Gas concentration and flow variation curve of pressure relief drainage borehole](image)

4.2.3. Analysis of tunneling pre pumping effect
During normal driving, the gas emission of heading face is significantly reduced, approximately linear attenuation, with the gas emission of 43 # southwest roadway attenuated at about 0.6 m³/min for every 100m increase in roadway length; 45 # southeast roadway attenuated at about 0.8 m³/min for every 100m increase in roadway length. The variation curve of gas emission is shown in Figure 5.
Through the comprehensive measures, the gas concentration in the upper corner of the fully mechanized working face is reduced from about 1.0% to less than 0.3%, the gas concentration in the return air flow is reduced from more than 0.6% to less than 0.2%, and the gas concentration in the return air flow of the heading face is reduced from about 0.8% to less than 0.4%. The gas overrun phenomenon is eliminated in the production process.

5. Conclusion

- Taking the gas of Wudong coal mine of Shenxin energy company as the research background, this paper uses the numerical simulation method to reveal the distribution and evolution law of surrounding rock stress field and fracture field of horizontal slicing mining face in steeply inclined coal seam, analyzes the gas flow process and law from the lower part of coal seam mining to slicing mining face, and determines the horizontal slicing mining face in steeply inclined coal seam. The main influencing factors of gas emission are analyzed.

- The comprehensive control measures combining the regional pressure relief gas interception and drainage with the stratified goaf buried pipe drainage were formulated and implemented, which realized the effective gas control of the mining face in the mine production process and adapted to the gas control of the coal seam in the steeply inclined and high gas mine.

- In the process of using this technology for reference, it is necessary to fully combine with the mine's own conditions to determine the reasonable prevention and control measures parameters and technology, and determine the measures suitable for the mine disaster management through continuous summary, analysis and optimization in practice.

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