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Research on the Countermeasures of Corner Gas Control in Coal Mine Working Face

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Abstract: At present, the Shanxi Lutaishan Mine uses high-level gas drilling combined with the upper-corner cannula extraction method to extract the gas in the mined-out area and the surrounding rock, but the effect is not ideal, which has caused great problems in the daily safety production of the coal mine. In order to effectively solve the problem of gas accumulation at the corner of the 2201 working face, the factors affecting the gas concentration at the upper corner are summarized, and the main reasons for the overrun of the corner gas at the 2201 working face are analyzed. Combined with the characteristics of the coal mine and the measures that have been adopted, three kinds of new upper corner gas control measures are proposed, namely long-distance large-aperture high-position fissure drainage borehole drainage, upper-corner skeleton air duct open drainage and goaf blockage, which provides new technical references for corner gas control in Lutaishan 2201 working face and ensures the normal safe and efficient production of coal mines.

Keywords Coal mine, Upper corner gas, Overrun, Gas extraction, Safe and efficient production

INTRODUCTION

The accumulation of gas in the corner of the coal mine face not only seriously threatens the health of the miners, but also has a high risk of explosion, causing economic losses that cannot be estimated by the coal mine enterprises, and even threatening the life safety of coal mine workers [Bai, et. al., 2020 and Peng, et. al., 2014]. In recent years, scholars have conducted a lot of research on the problem of corner gas accumulation and overrun in coal mine working faces, and have achieved certain results. Lin Baiquan et al. [Lin, et. al., 1997] proposed to increase the air leakage sink and reduce the air leakage in the goaf to treat the gas in the upper corner of the goaf. Mo Dabiao, Zhou Aitao, et al. [Mo, et. al., 2014 and Zhou, et. al., 2015] proposed to treat the upper corner gas by burying pipes in goaf. Chang Baoping [Chang, 2019] solved the problem of gas overrun at the corner of fully mechanized caving face by using temporary corner windows, increasing gas supply in coal mining face, setting up windshields in goaf area, and installing special exhaust fans. Guan Jiangang [Guan, 2020] adopted the drainage measures along the empty road to solve the hidden danger of gas accumulation in the upper corner. Wang Kaiwang [Wang, 2020] used super-large-diameter boreholes to treat the upper corner gas. The height of the final hole of the borehole was increased from 1.6m to 3m on average, and the construction efficiency was increased by 61%. Dong Zhenjun [Dong, 2012], Bai Gang [Bai, et. al., 2020] proposed high-level drilling to solve the upper corner gas limit.

Lutaishan Mine is affiliated to Shanxi Coal Import and Export Group. It is approved to mine No.2 and No.15 coal seams, with a mining depth from +940m to +610m, a mine field with an east-west width of 1.5~2.0km, a north-south length of 2.6km, the area is 4.7km^2 and the production capacity is 600,000t/a. The 2$^{\#}$ coal seam is being mined in the mine, and the 2201 working face is being mined. The length of the cut is 160m, the length of the incline is 1210m, and the average coal thickness is 2.2m. The working surface is ventilated by one-in-one, single-U ventilation. At present, the Lutaishan Mine mainly adopts the method of high-level drilling and drainage of roof crack gas to supplement the gas in the goaf to treat the corner gas on the working face, but the effect is not very satisfactory. During the mining of the working face, a large amount of gas is emitted from the mined-out area and surrounding rock. The working face, upper corner and return air flow all show gas overruns in different degrees, which restricts the normal and safe production of the mine. Therefore, in view of the current problem of gas accumulation and overrun at the upper corner of Lutaishan Mine, it is urgent to explore suitable measures for gas control.

INFLUENCING FACTORS OF GAS CONCENTRATION IN UPPER CORNER

Gas concentration usually refers to the volume concentration, which is the volume of gas contained in the unit volume of wind flow, which is affected by the amount of wind and gas emission. The corner air volume on the coal mining face is easily affected by

the ventilation method, and the gas emission is affected by factors such as gas content in the coal seam, air leakage in the goaf, coal output, coal falling technology, and roof management.

(1) Ventilation method. Coal mining face mainly includes U-shaped, Y-shaped, W-shaped, Z-shaped and H-shaped ventilation modes, and most coal mining face in China adopt U-shaped ventilation mode. The airflow of the working face passes through the corner of the coal mining face before entering the return air lane. The resistance increases and the wind speed decreases, resulting in insufficient air flow at the upper corner and easy to cause gas accumulation at the upper corner.

(2) Gas content of coal seam. The gas content of coal rock layer is the decisive factor affecting the gas concentration in the upper corner. The higher the gas content, the greater the gas emission from the working face. Under the same ventilation conditions, the gas concentration in the upper corner is more likely to exceed the limit. Gas drainage and liberation are usually used to prevent gas accumulation in the upper corner.

(3) Air leakage in the mined-out area. According to the actual conditions on the mine and the results of correlation analysis, it is concluded that half of the gas at the corner of the working face comes from the working face, and most of it comes from the gas carried by the air leakage in the goaf. Therefore, the more serious the air leakage in the goaf, the greater the gas concentration in the upper corner.

(4) Coal production. The “12-character policy” of gas control includes determining production by wind, which means that the coal production of the mine must be determined according to the amount of air. Since the gas content and air volume of the coal seam are basically unchanged, the greater the output of the working face, the greater the gas emission. The higher the gas concentration, the easier it is to cause gas accumulation in the upper corner.

(5) Coal falling process and roof management. The coal falling process is the main factor that affects the amount of gas emission. The relevant statistics show that compared with the normal gas emission, the gas emission of the coal mining machine increases to 1.3 to 1.6 times when the coal is mined, and when the coal is fired, it is increased to 1.4 to 2.0 times. The mechanization of most mines in China is not high, and the mining conditions are complicated, which makes the coal falling process relatively backward. At the same time, the lack of safe investment and the complicated geological conditions lead to the destruction of the roof stress, causing the roof to fall and make the goaf. The amount of gas gushing increased, and eventually a high concentration of gas was accumulated in the upper corner.

ANALYSIS OF CAUSES OF GAS OVERFLOW AT CORNER OF 2201 FACE

According to the gas emission law of the mined-out area and surrounding rock and the air flow state under the "U" ventilation mode, the main reasons for the corner gas overrun on 2201 working face are as follows:

(1) Influence of goaf, surrounding rock gas emission and roof pressure.

A large amount of gas accumulates in the coal left over from the goaf, which is the main source of gas flowing into the face. In addition, the direct and basic roofs of No.2 coal seam have poor permeability and good wall rock sealing, which is not conducive to the release of gas, and much gas has been preserved. At the same time, there is a thin coal seam under No. 2 coal seam, which is within the influence range of mining, and gas will be released into the goaf. When the roof of the working face is pressed periodically, a large amount of high-concentration gas in the goaf is squeezed out, so that a large amount of high-concentration gas accumulates in the upper corner, which is a main reason for the upper corner gas overrun.

(2) Air leakage in goaf.

The location of the upper corner determines that the wind flow is in a breeze turbulent state, which is not conducive to the normal discharge of gas. At the same time, in the "U" type ventilation mode, the wind flow entering the goaf brings the high concentration gas in the goaf into the upper corner. The air leakage at the working face is proportional to the amount of gas brought into the upper corner. It is also a major cause of gas overrun at the upper corner.

(3) The state of wind in the upper corner.

In the "U" type ventilation mode, the corner of the working face is close to the coal wall and the goaf side, the wind speed is low, and the part is in a vortex state. This vortex makes it difficult for the gas from the goaf to enter the main wind flow, so that the high-concentration gas circulates around the corner and gathers in the vortex area, causing the gas in the upper corner to exceed the limit. If the corner at the corner of the working face is lagging back to the top of the column, in addition to the eddy current area at the corner, there will be a breeze area near the top row of cut columns, and the gas leaking from the goaf will accumulate here. In this way, it is easier to form a gas limit in the upper corner.

CORNER GAS CONTROL MEASURES ON 2201 WORKING FACE

At present, the upper corner gas control measures mainly include ground drilling method, tail tunnel method, pipe insertion (buried) method, roof high extraction tunnel method, ordinary high-level drilling method and so on. According to the actual situation of the Lutaishan coal seam, referring to the effect of the high-drilling hole and goaf intubation extraction measures, on the basis of analysis and determination of the gas source at the upper corner and the cause of gas overrun, it is

proposed that the corner gas control on the 2201 working face mainly adopts three measures: (1) Long-distance large-aperture high-position fissure extraction drilling is used to extract the upper corner area and the goaf gas, and the upper corner gas problem is fundamentally solved. (2) Use the return air along the channel to lay the gas drainage pipeline to enhance the drainage of the upper corner gas. (3) Plugging, that is, to reduce the air leakage in the goaf and cause a large amount of gas to flow out into the upper corner.

Long-distance large-aperture high-position fissure drainage drilling

In order to ensure that the borehole has a longer extraction time, a larger extraction range, and a higher gas extraction rate, combined with the coal bed occurrence conditions in the 2201 fully mechanized coal mining face, according to the movement law of roof covering rock and pressure relief in the stope. The O-ring theory calculations show that the reasonable layout of the long-distance large-aperture high-position fissure drilling boreholes in Lutaishan Mine should be a straight distance of 30.0m and a horizontal distance from the return air lane of 17.3~77.3m. Considering the borehole spacing of 10m, it is suitable to arrange 5 long-distance large-aperture high-position fissure extraction boreholes in the optimal area of the gas at the angle of extraction. The length of the main borehole is 300m and the diameter of the final hole is 96mm. In order to improve the gas effect in the upper corner area of the borehole drainage, a branch is opened every 50m during the construction of the two main holes in each drill site, and the length of the branch hole is about 50m. The location of the long-distance, large-aperture, high-position fracture extraction drilling holes is shown in Figure 1.

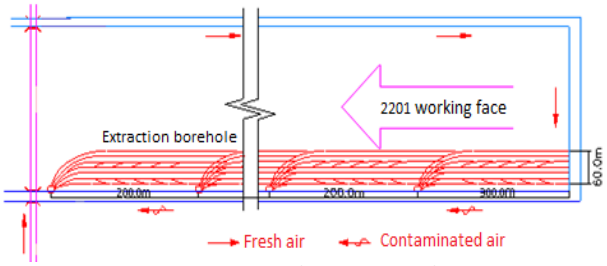

Figure 1. Schematic diagram of plane layout of long-distance large-aperture high-position fracture extraction drilling

Open extraction of the upper corner skeleton air duct

In view of the limited effect of gas overrun control at the upper corner of the goblet gas drainage area in Lutaishan Mine, the open-end extraction method of the upper corner skeleton wind tube is considered. A separate gas drainage pipeline is installed in the 2201 return air flume. The pipeline adopts the existing Φ273 steel pipe of the mine. Considering the parameter design and extraction data of the open extraction of the air cylinder, the temporary design connects the open air cylinder to the extraction pipeline in the goaf. The size of the open air cylinder is equal to the diameter of Φ273 steel pipe. Install a butterfly valve on the pipeline to adjust the negative pressure of the air cylinder in real time, and install flow and negative pressure measurement equipment at the same time.

According to the actual situation on the site, a butterfly valve is connected to the end of the extraction pipeline in the 2201 return air flume goaf. At the same time, an orifice flowmeter is installed at the rear end of the butterfly valve. Then connect the equal diameter retractable negative pressure air cylinder, the connection length of the air cylinder is 20m (two sections), and the innermost end of the air cylinder is tied with iron gauze to prevent the inhalation of debris. As the working surface progresses, gradually move the position of the air duct vent according to the length of the air duct to ensure the gas drainage effect at the upper corner. The air cylinder is hung on the roadway and placed neatly. It is about 0.6-0.8m away from the roof. It can hang the coal seam roof. The front end of the air cylinder is located below the gas probe and is 1 to 2m toward the goaf.

In the early stage, it can consider using open extraction for testing. If the test effect is not good, or the drainage effect of the upper corner intubation needs to be strengthened, the intubation extraction area needs to be sealed. In the early stage, it can be airtight and air curtain can be used. Hang the air curtain to the upper corner area to stop the gas from escaping and strengthen the extraction. Since the air curtain still has air leakage, if the expected effect is not achieved, the coal slag can be packed on the top cutting line and the wall construction method near the outermost hydraulic support. The masonry wall should be completed in time as the working surface advances, and always ensure that the extraction pipe is within the closed wall for extraction. The distance between closed walls is 3~5m.

The gas drainage of the upper corner fan ensures sufficient negative pressure, and at the same time considers the maximum negative pressure bearing capacity of the fan. The joint between the air cylinder and the extraction pipeline is to ensure no air leakage. If the air leakage is detected when connecting the air cylinder joint, it must be dealt with in time. The negative pressure of extraction is adjusted by the butterfly valve in the extraction pipeline. Considering the maximum pressure of the skeleton fan, the negative pressure of the initial extraction is controlled at about 3-5Kpa, and the

on-site adjustment will be carried out according to the test conditions and needs in the later period. It must be ensured that the skeleton fan is not damaged by the negative pressure.

The removal and installation of the extraction pipe of the goaf branch must be in the maintenance class. Before the disassembly, the tile inspector measured the gas concentration in the upper corner and reported it to the relevant department leaders. After approval, it must be quickly disassembled and completed the installation (requires 5 workers). As the skeleton air cylinder advances with the working surface, each worker must arrange for 2 workers to move forward, check the pipeline for leaks after placing it in place, and immediately take measures to plug the leak if it is found. After the completion of each cycle of extraction, under the premise of ensuring safety, in principle, the skeleton air cylinder needs to be recycled and reused. The preparation of the materials required for the open extraction at the upper corners of the skeleton-type fan is shown in Table 1.

Table 1 Upper corner cannula material

Serial number	Material name	Model	Quantity
1	Skeleton fan	D273mm	30m (10m each)
2	Butterfly valve	—	1
3	Orifice flowmeter	—	1
4	Spiral welded steel pipe	D273mm	15m
5	Strainer	—	1

Goaf blockage

In the single U-shaped ventilation system, the fresh air flow enters the working face from the air inlet lane, dilutes and takes away the gas from the working face and enters the return air lane, but in the actual ventilation system, when the fresh air flow enters the working face from the air inlet lane It is inevitable that a small part of the wind current will leak into the goaf, forming a leaking air flow, as shown in Figure 2. The air leakage current will bring the gas in the goaf out of the upper corner through the mining gap, causing the upper corner gas to exceed the limit.

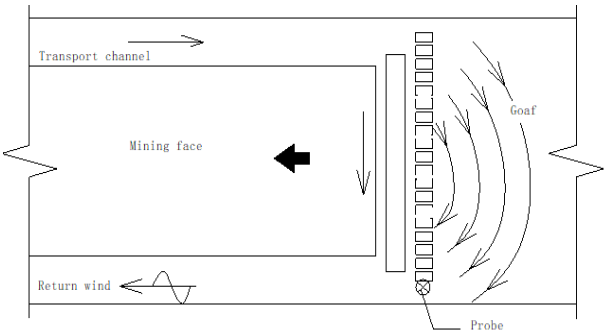

Figure 2. Single U-shaped ventilation air flow direction

In order to reduce the air leakage in the lower corner goaf and the gas emission in the upper corner goaf, the goaf behind the upper and lower corners is blocked. The blocking measures can be by means of loess filling, spraying, and coal cladding. In the early stage, the use of coal cladding for wall filling can be considered to reduce air leakage. In addition, after the closed area is formed at the upper corner, the closed area can be drained. At the beginning of the test, the lower corner can be blocked, and then the upper corner can be blocked according to the blocking effect.

CONCLUSION

In this paper, by analyzing the factors affecting the gas concentration at the upper corner and the reasons for the corner overrun at 2201 working face of Lutaishan Coal Mine, three measures are put forward: using long-distance large-aperture high-position fissure drilling holes to extract gas and gas in the upper corner area and goaf, the use of return air along the channel to lay gas drainage pipelines to enhance the drainage of upper corner gas, the goaf is blocked to reduce air leakage in the goaf and cause a large amount of gas to flow out into the upper corner. It provides a reference for the treatment of the corner gas in the face of Lutaishan Mine in the future, and provides a technical guarantee for the safe and smooth mining of the face.

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