ISSN: 1813-4890

Analysis of Causes for Gas Overrun in the Upper Corner of Mining Faces and Its Comprehensive Control Measures

Bing Li [1,2]

[1] China Coal Technology and Engineering Group Chongqing Research Institute, Chongqing 400039, China;

[2]State Key Laboratory of Coal Mine Disaster Prevention and Control, Chongqing 400039, China

Abstract

In response to the issue of gas overrun in the upper corner of the 2201 working face, this paper analyzes the reasons for the poor effectiveness of the existing high-level gas drilling combined with upper corner intubation extraction method and its impact on safe production. Through a systematic study of the factors influencing gas concentration in the upper corner, three targeted control measures are proposed: (1) Employing long-distance, large-diameter high-level fracture extraction drilling to enhance gas extraction efficiency from adjacent seams. (2) Implementing open extraction via a framework air duct in the upper corner to optimize local ventilation. (3) Strengthening the sealing of the goaf to reduce air leakage channels. Field applications demonstrate that the comprehensive measures effectively resolve the issue of gas accumulation, providing a replicable technical solution for mines under similar conditions and significantly improving the level of safe and efficient coal mine production.

Keywords

Gas control; Upper corner gas; Overrun; High-level drilling extraction; Framework air duct; Goaf sealing.

1. Introduction

Gas accumulation in the upper corner of coal mine working faces is a major challenge for coal mine safety production, posing a severe threat to the health of mining personnel and increasing the risk of explosions, resulting in substantial economic losses for coal mining enterprises [1-3]. In recent years, scholars have conducted extensive research on gas accumulation and overrun issues in the upper corners of coal mine working faces, achieving certain results. Ni Lianqin et al. [4] proposed a staggered double-buried-pipe gas extraction technology for the upper corner. Li Donglong [5], taking the 80103 working face of Caojiashan Mine as the engineering background, adopted large-diameter drilling gas extraction technology to extract gas from the upper corner of the goaf and used numerical simulation software to analyze the drilling gas flow under different extraction negative pressures and drilling diameters, determining the optimal extraction negative pressure to be -30 kPa and the optimal drilling diameter to be 130 mm. After determining the construction parameters, industrial trials of large-diameter drilling gas extraction were conducted, and it was found that when large-diameter drilling was used for upper corner gas extraction, the gas concentration in the upper corner was maintained at 0.2%, indicating a relatively good extraction effect. Liu Xiaoping [6] designed a high-level extraction roadway for the 15309 working face of Sijiazhuang Coal Mine, with a horizontal distance of 10 m and a vertical distance of 14 m, and the maximum gas volume fraction in the upper corner of the working face was 0.44%. Chu Fuhao [7] extracted gas from the goaf using large-diameter drilling and from the overlying fracture zone using high-level drilling. However, after adopting the high-level gas drilling combined with upper corner intubation extraction method at Shanxi Lutai Mountain Mine, the gas control effect was still unsatisfactory, affecting the normal and safe production of the mine. Therefore, it is particularly important to explore gas control measures suitable for the 2201 working face of Lutai Mountain Mine.

2. Analysis of the Causes of Gas Overrun in the Upper Corner of the Working Face

Lutai Mountain Mine, affiliated with Shanxi Coal Import and Export Group, is approved for mining coal seams 2 and 15, with a mining depth ranging from +940m to +610m. The mine field spans 1.5-2.0km east-west and 2.6km north-south, covering an area of 4.7km², with a production capacity of 600,000 tons per annum. Currently, the mine is extracting coal seam 2#, specifically the 2201 working face, which has a cut-through length of 160m, a dip length of 1210m, and an average coal thickness of 2.2m. The working face employs a single "U" ventilation system with one intake and one return airway. Gas concentration typically refers to volume concentration, representing the volume of gas contained in a unit volume of airflow, influenced by both air volume and gas emission rate. The air volume in the upper corner of the coal mining face is easily affected by the ventilation method, while the gas emission rate is influenced by factors such as coal seam gas content, goaf air leakage, coal production, coal caving technology, and roof management [8-10]. Based on the analysis of gas emission patterns from the goaf and surrounding rock, as well as the airflow state under the "U"-type ventilation method, the main causes of gas overrun in the upper corner of the 2201 working face are as follows:

(1) Impact of gas emission from the goaf, surrounding rock, and roof pressure

The residual coal in the goaf contains a large amount of gas, which is the primary source of gas influx into the working face. Additionally, the immediate roof and main roof of coal seam 2# have poor permeability and good sealing properties, which are not conducive to gas release, resulting in a significant accumulation of gas. Furthermore, there is a thin coal seam beneath coal seam 2# within the mining influence range, which releases gas into the goaf. When the roof of the working face undergoes periodic pressure, a large amount of high-concentration gas is expelled from the goaf and accumulates in the upper corner, which is a major cause of gas overrun.

(2) Goaf air leakage

The location of the upper corner results in its airflow being in a weak turbulent state, which is not conducive to the normal discharge of gas. Meanwhile, under the "U"-type ventilation method, the airflow entering the goaf carries high-concentration gas into the upper corner. The amount of air leakage in the working face is directly proportional to the amount of gas carried into the upper corner, which is also a major cause of gas overrun.

(3) Airflow state in the upper corner

Under the "U"-type ventilation method, the upper corner of the working face is adjacent to the coal wall and the goaf side, with low airflow velocity and local eddy currents. These eddy currents make it difficult for the gas emitted from the goaf to enter the main airflow, causing high-concentration gas to circulate near the corner and accumulate in the eddy current zone, resulting in gas overrun. If there is a delay in caving the roof props at the upper corner of the working face, in addition to the eddy current zone, a weak airflow zone will appear near the caving row props, where gas leaked from the goaf accumulates, further contributing to gas overrun in the upper corner.

3. Gas Control Measures for the Upper Corner of the 2201 Working Face

Currently, the main gas control measures for the upper corner in China include surface drilling, tail drift, intubation (embedding) pipe, high-level roof extraction drift, and ordinary high-level drilling methods. Based on the actual conditions of coal seam occurrence at Lutai Mountain Mine and referring to the effects of the currently adopted high-level drilling combined with goaf intubation extraction measures, three main gas control measures are proposed for the upper corner of the 2201 working face: the first is to use long-distance, large-diameter high-level fracture extraction drilling to extract gas from the upper corner area and the goaf, fundamentally solving the gas problem in the upper corner; the second is to lay gas extraction pipelines along the return airway to strengthen gas extraction from the upper corner; the third is sealing, which involves reducing air leakage from the goaf to prevent a large amount of gas from surging into the upper corner.

3.1. Long-distance, large-diameter high-level fracture extraction drilling

To ensure a long extraction time, a large extraction range, and a high gas extraction rate for the drilling, combined with the coal seam occurrence conditions of the 2201 fully mechanized mining face, and based on the movement law of the overlying strata in the mining stope and the pressure relief "O"-ring theory, the reasonable layout horizon for long-distance, large-diameter high-level fracture extraction drilling at Lutai Mountain Mine is calculated to be 30.0m vertically, with a horizontal distance range of 17.3-77.3m from the return airway. Considering a drilling spacing of 10m, five long-distance, large-diameter high-level fracture extraction drillings are suitable for arranged in the optimal area for extracting gas from the upper corner. The main drilling length is 300m, with a final hole diameter of 96mm. To improve the gas extraction effect in the upper corner area through the drilling, branches are opened every 50m during the construction of the two main holes in each drilling site, with each branch hole being approximately 50m long. The layout positions of the long-distance, large-diameter high-level fracture extraction drillings are shown in Figure 1.

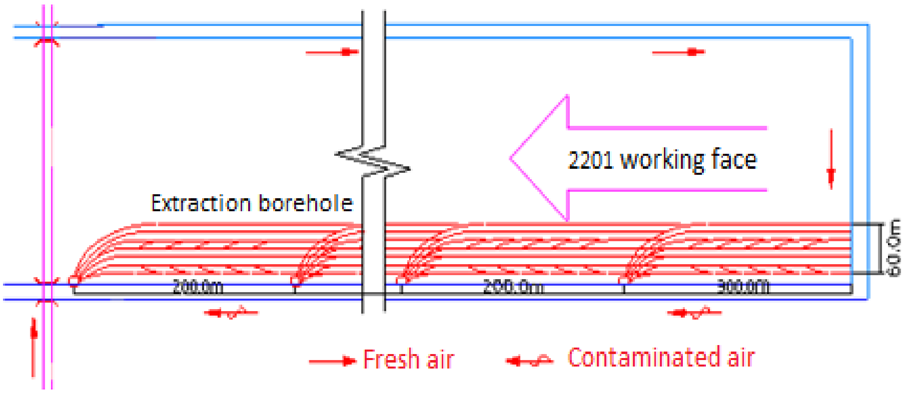

Figure 1 Schematic diagram of plane layout of long-distance large-aperture high-position fracture extraction drilling

3.2. Open Extraction via Framework Air Duct in the Upper Corner

Given the limited effectiveness of intubation extraction for goaf gas control in addressing gas overrun in the upper corner at Lutai Mountain Mine, the method of open extraction using a framework air duct in the upper corner was considered, with gradual improvements explored during the trial process. A separate gas extraction pipeline was installed in the 2201 return airway, utilizing the mine's existing Φ273 steel pipes. Considering the parameter design and extraction data for open extraction via the air duct, it was tentatively designed to connect the open air duct to the goaf extraction pipeline, with the open air duct being of the same diameter as the Φ273 steel pipe. A butterfly valve was installed on the pipeline to adjust the extraction negative pressure of the air duct in real-time, along with flow and negative pressure measurement equipment. Based on the actual site conditions, a butterfly valve was connected at the end of the goaf extraction pipeline in the 2201 return airway, and an orifice plate flowmeter was installed downstream of the butterfly valve. An extensible negative pressure air duct of the same diameter was then connected, with a connection length of 20m (two sections).

As the working face advanced, the position of the air duct outlet was gradually moved according to the length of the air duct to ensure effective gas extraction in the upper corner. The air duct was hung neatly against the roadway side, approximately 0.6-0.8m from the roof, and could be suspended from the coal seam roof. The front end of the air duct was positioned below the gas probe, 1-2m towards the goaf. Initially, open extraction could be considered for trials. If the trial results were unsatisfactory or if the intubation extraction effect in the upper corner needed to be enhanced, the intubation extraction area would need to be sealed. In the early stages, sealing could be achieved using wind curtains hung in the upper corner area to block gas emission and strengthen extraction. Due to potential air leakage from wind curtains, if the expected results were not achieved, alternative methods such as filling with coal cinder bags and constructing walls along the caving line and near the outermost hydraulic supports could be employed. The walls should be constructed promptly as the working face advances, ensuring that the extraction pipeline remains within the sealed walls for extraction. Sealed walls should be spaced at intervals of 3-5m.

Sufficient negative pressure should be maintained for gas extraction via the air duct in the upper corner, while also considering the maximum negative pressure tolerance of the air duct. The joints between the air duct and the extraction pipeline must be sealed to prevent air leakage, and any leaks detected at the air duct joints must be promptly addressed. The extraction negative pressure is adjusted via the butterfly valve in the extraction pipeline. Considering the maximum pressure tolerance of the framework air duct, the initial extraction negative pressure should be controlled at around 3-5Kpa, with on-site adjustments made later based on trial results and needs, ensuring that the framework air duct is not damaged by the negative pressure.

3.3. Goaf Sealing

In a single U-shaped ventilation system, fresh airflow enters the working face from the intake airway, dilutes and carries away the gas from the working face, and enters the return airway. However, in actual ventilation systems, a small portion of the fresh airflow inevitably leaks into the goaf when entering the working face from the intake airway, forming leakage airflow, as shown in Figure 2. This leakage airflow carries gas from the goaf through mining voids to the upper corner, causing gas overrun.

To reduce air leakage from the goaf in the lower corner and gas emission from the goaf in the upper corner, sealing measures should be implemented in the goaf behind the upper and lower corners. Sealing methods could include loess filling, shotcreting, and constructing walls with coal cinder bags. In the early stages, constructing walls with coal cinder bags could be considered to reduce air leakage. Additionally, after forming a sealed area in the upper corner, extraction could be carried out in the sealed area. Initially, sealing could be performed in the lower corner, followed by sealing in the upper corner area based on the sealing effect.

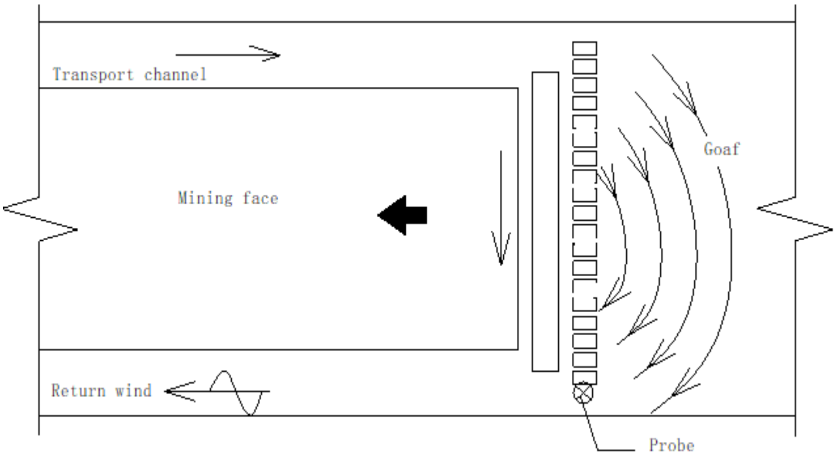

Figure 2 Single U-shaped ventilation air flow direction

4. Conclusion

This paper conducted an in-depth analysis of the causes of gas overrun in the upper corner of the 2201 working face at Lutai Mountain Mine in Shanxi Province and proposed targeted control measures. Through a systematic study of the factors influencing gas concentration in the upper corner, combined with the actual conditions at Lutai Mountain Mine, the following main conclusions were drawn:

(1) The main causes of gas overrun include gas emission from the goaf and surrounding rock, roof pressure, air leakage from the goaf, and low airflow velocity in the upper corner.

(2) Control measures such as long-distance, large-diameter high-level fracture extraction drilling, open extraction via a framework air duct in the upper corner, and goaf sealing were proposed.

(3) Field applications demonstrated that after comprehensively adopting the above three control measures, the problem of gas accumulation in the upper corner of the 2201 working face at Lutai Mountain Mine was effectively resolved, with a significant reduction in gas concentration, ensuring safe and efficient coal mine production.

References

[1] Liang Yunpei, Li Shang, Li Quangui, et al. Prediction of Gas Concentration in the Upper Corner of Coal Mining Face Based on FEDformer-LGBM-AT Architecture [J]. Journal of China Coal Society, 2025, 50(01): 360-378.

[2] Cui Cong. Discussion on Prevention and Control Methods for Gas Overrun in the Upper Corner of Mining Faces [J]. China Coal, 2022, 48(04): 48-53.

[3] Gao Dengyun, Li Ruiqun. Research on Gas Control Technology in the Upper Corner of Fully Mechanized Mining Faces in Shendong Mining Area [J]. Coal Engineering, 2023, 55(04): 87-91.

[4] Ni Lianqin, Gao Jie. Research on Technical Parameters of Double-Buried-Pipe Gas Extraction with Staggered Distance in the Upper Corner [J]. Coal Engineering, 2022, 54(05): 63-67.

[5] Li Donglong. Research on Gas Control Technology in the Upper Corner Using "Hole Instead of Roadway" with Large-Diameter Drilling [J]. Western Exploration Engineering, 2022, 34(12): 135-136+139.

[6] Liu Xiaoping. Research on Gas Control Technology in the Upper Corner of Fully Mechanized Mining Faces Using High-Level Extraction Roadway [J]. Coal, 2024, 33(12): 36-39.

[7] Chu Fuhao. Application of Gas Control Technology in the Upper Corner of Fully Mechanized Mining Faces [J]. Energy Technology and Management, 2025, 50(01): 40-42.

[8] Bi Cunguang, Hua Shuai, Tian Kunyun. Grey Relational Analysis of Influencing Factors for Gas Accumulation in the Upper Corner of Coal Mining Faces [J]. Energy and Environmental Protection, 2020, 42(08): 15-18.

[9] Li Hangzhou, Wang Fei, Liu Hongwei, et al. Research on the Effect of Air Curtain on Air Leakage in Goaf and Gas Accumulation in the Upper Corner [J]. Mining Research and Development, 2024, 44(10): 167-173.

[10] Yin Xiaoyi. Causes and Control Measures for Gas Overrun in the Upper Corner of Mining Faces [J]. Petrochemical Industry Technology, 2023, 30(03): 259-260.