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Research on Reasonable Hole Arrangement Parameters of Ground Drilling Gas Extraction Technology

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Abstract*:* Ground drilling gas extraction technology is an effective technical means for coal mine gas control and CBM development. In order to obtain a reasonable gas drilling hole pattern for ground drilling, CFD numerical simulation technology was used to study the gas flow and distribution law in the goaf of the coal mine working face, and reasonable parameters such as the position and spacing of ground hole drilling were obtained. The research shows that the surface wells are arranged at a distance of 20 ~ 70m from the return air level roadway, and the ground drilling interval in the geological structure zone is 150m × 150m. This article has important guiding significance for the popularization and application of ground drilling gas drainage technology.

Keywords Coal mine, Ground drilling, Gas drainage, Hole layout, CFD numerical simulation

INTRODUCTION

China's coalbed methane disaster is serious, and ground drilling gas extraction technology is an effective technical means for coal mine gas control and coalbed methane development [Zhou, *et. al.*, 2006, Zhou, 2011]. The original ground drilling technology is mainly used as a large-scale development technology of coalbed methane. The drilling holes are mainly arranged in the coal seam anticline shaft and anticline and anticline wing parts, and the drilling interval is 300m × 300m. With the mature application of ground drilling technology in the coal mine industry, surface drilling technology has begun to transform from a coal bed methane development technology to an effective regional gas pre-drainage outburst prevention measure. In recent years, scholars at home and abroad have conducted in-depth research on the ground drilling gas extraction technology, and have achieved rich results. At present, Australia has widely used the vertical borehole extraction technology in the ground goaf. Li Minghao et al. [Li, *et. al.*, 2000] analyzed the feasibility of ground drilling to drain gas in goaf, and summarized the principles and construction techniques of ground drilling. Liang Yunpei [Liang, 2007] used field test and numerical simulation to study the different factors affecting the drilling effect and service period of ground drilling in Huainan mining area, and obtained ground drilling drainage will greatly reduce the gas content of the return air flow at the working face. Lian Faxian [Lian, 2012] analyzed the key factors for the completion of wells, and successfully tested the ground extraction gas drilling technology in Xinji No.1 Coal Mine. The rate of completion of the constructed gas drainage well was 100%. Qin Jinhui [Qin, 2018] implemented ground drilling in Liyazhuang Coal Mine, with a extraction concentration of 16.2%. Zhang Yan [Zhang, 2019] analyzed the deformation and failure mechanism of ground drilling under the influence of mining, and proposed the efficient ground gas drainage technology in goaf.

According to the characteristics of coal seam outburst, the outburst point is mostly in the geological structure zone (fault or syncline axis). The coal seam in this area is poorly ventilated. To achieve regional outburst prevention, ground drilling should not only be arranged on the anticline axis and the anticline and anticline wings, but also should be placed in the geological structure zone, through the fracturing of surface wells, to improve the permeability of the geological structure zone, and to achieve the outburst prevention in the structural area. At the same time, considering the high cost and long cycle of ground drilling, it should be combined with pioneering mining methods as far as possible to achieve the purpose of 'one well for multiple purposes'. Therefore, the CFD numerical simulation technology was used to study the gas flow and distribution law of the underground mined-out area, and to determine a reasonable ground drilling layout.

CFD NUMERICAL SIMULATION ANALYSIS

Engineering Background

The gas flow law in the mined-out area is very complicated. It involves many factors, such as ventilation, gas density, buoyancy and permeability of the mined-out area. A coal mine working face as the research background was selected. The mine mainly mines $3^{\#}$ coal seam, the seam inclination angle is 2 ° ~ 10 °, generally about 5 °, and the coal seam thickness is 6.31m. The coal quality is relatively hard, and the coal's firmness coefficient is 1 ~ 2. The gas content of the coal in the $3^{\#}$ coal seam is 15.04 ~ 21m^3/t, and the remaining amount is 3.52m^3/t.

Using a horizontal development of 3# coal seam, the horizontal elevation is +280m level, and a total of 4 mining areas are divided. The design of the working face adopts the long wall retreat type full mining coal mining method.

Numerical Model Building

CFD (Computational Fluid Dynamics) uses electronic computers as tools and applies various discretized mathematical methods to conduct numerical experiments, computer simulations, and analytical studies on various types of fluid mechanics problems to solve various practical problems [Ding, *et. al.*, 2013]. The geometric model of the mining face CFD model is shown in Figure 1. The detailed basic parameters of the modeling are shown in Table 1. In the process of simulation analysis, the gas distribution flow field before and after ground drilling was simulated to analyze the ability of ground drilling to extract the gas in the goaf and the overall gas distribution law in the goaf.

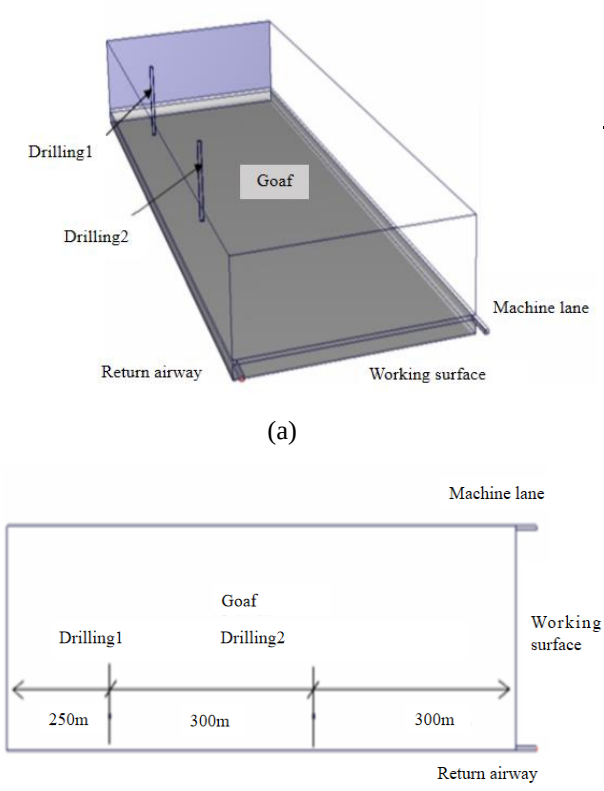


Figure 1. CFD geometric model of mining face

Table 1 Basic parameters of working face CFD model

Number	Model parameters	Parameter value
1	Working surface size	Length 780m, width 240m, height 3.0m
2	Roadway size	Width 4m, height 3.0m(12m^2)
3	CFD model dimensions-top and bottom	100m high - including 65m above and 35m below
4	Coal seam tilt -Vertical working surface (propulsion) direction and Along the working surface (advance) direction	3°, the return air level is at the lower part (12m below the transport level), and the working surface level is about 50 ～ 60m higher than the cutting eye
5	Ventilation system	U-shaped ventilation, 2600m^3/min
6	Gas emission from goaf	The whole goaf 350L/s～650L/s
7	Gas composition	100% CH_4
8	Gas drainage in goaf	Drilling hole in goaf

Simulation Results Analysis

Through the above settings, the gas distribution law inside the mined-out area when the ground drilling is not working is shown in Figure 2, and the gas distribution in the mined-out area under different working conditions is shown in Figure 3.

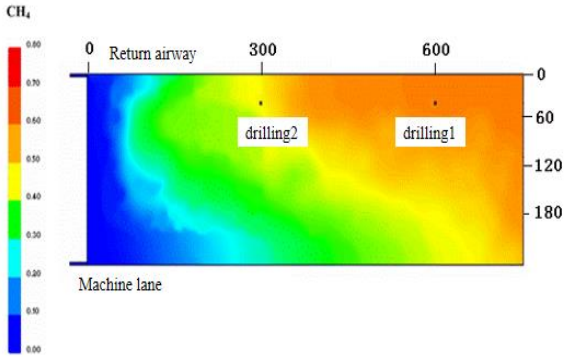
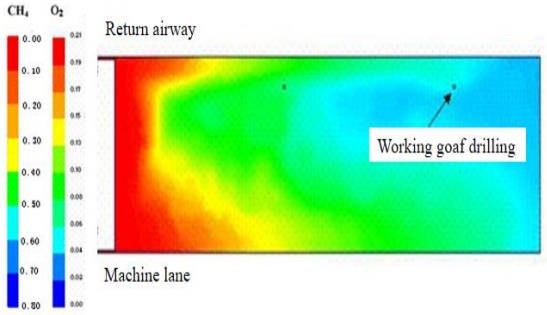


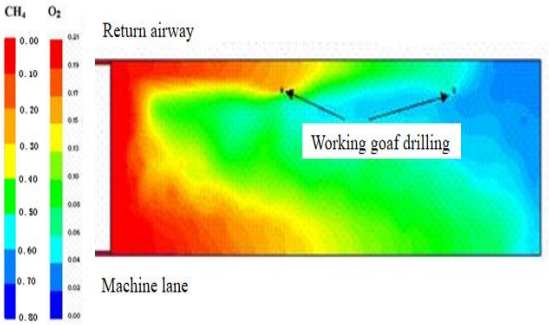
Figure 2. CFD simulation of gas distribution in goaf

From the Figure 2, the amount of oxygen entering the goaf is very high, especially the oxygen concentration on the side of the air inlet 300m behind the working face can exceed 12%. Oxygen accumulates on the return air lane side 150m behind the working face, and the maximum gas concentration on the return air lane side of the goaf can reach 80%. This indicates that the gas drainage holes in the ground goaf are arranged 20 ~ 70m away from the return air lane, and the gas with high concentration in the goaf can be extracted. This understanding is very important for optimizing the design of gas drainage boreholes in the ground goaf

and for designing the gas drainage system in the goaf and achieving a better drainage effect.



(a) Only the first drilling job



(b) Two drill holes work simultaneously

Figure 3. Gas distribution in goaf under different extraction conditions in working face

From the Figure 3, when 40kPa extraction negative pressure is applied to the ground borehole, the distribution of gas and oxygen flow field inside the goaf of the working face is predicted under different drilling combinations, and the distribution of gas flow field is completely opposite to that of oxygen.

POSITION AND SPACING OF GROUND DRILLING LAYOUT

According to the research on the influencing factors of regional outburst prevention and the above-mentioned CFD numerical simulation analysis results, the selection principles of the location and spacing of the outburst prevention wells in the surface drilling area can be obtained.

(1) Drilling position

Ground drilling should not only be arranged in the anticline axis and anticline and anticline wings, but also in the geological structure zone. Surface wells should also be considered to be placed 20 to 70 m away from the return air level roadway.

(2) Drilling distance

According to the numerical simulation results and the analysis of ground drilling and drainage data in the well field of Dongjing District, it is preliminarily determined that the ground drilling interval used for anti-outburst in the normal area is 300m × 300m, and the ground drilling interval in the geological structure zone is 150m × 150m.

CONCLUSION

The CFD numerical simulation of the working face is used to analyze the gas flow and distribution law in the mined-out goaf area, and a reasonable ground drilling layout position and drilling spacing are determined.

(1) Gas drainage holes in the ground goaf will be arranged at a distance of 20 ~ 70m from the return air lane to extract the gas with high concentration in the goaf. When a 40kPa extraction negative pressure is applied to the ground borehole, the distribution of gas flow field and oxygen distribution are completely opposite in the case of different borehole combinations.

(2) The surface wells are arranged at a distance of 20 ~ 70m from the return air level roadway, and the ground drilling interval in the geological structure zone is 150m ×150 m.

(3) The research results of this article provide a reference for the efficient extraction of gas ground.

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