CFD Simulation of Symbiotic Disaster Arising from Gas Explosion and Spontaneous Combustion in Longwall Mining Gobs

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**Keywords:** CFD model, Goaf, Coal spontaneous combustion, Gas explosion, Multiple field coupling, Gas flow field.

**Abstract.** With the increasing of mining depth, the symbiotic disaster of gas and coal spontaneous combustion is gradually increasing. In order to explore the multi-field coupling law of gas and coal spontaneous combustion in the goaf, the numerical simulation method was used to optimize the key parameters and find the best balance between effectively controlling the gas without expanding the danger zone of spontaneous combustion. The results show that, the higher the level of the high-level drainage roadway, the better the drainage effect, but considering the spontaneous combustion period, it is necessary to reasonably calculate the optimal drainage roadway layout position; the buried pipe extraction has good effect on gas control, but it is not conducive to fire prevention.

**Introduction**

With the rapid and sustainable development of China's economy, the demand for coal is increasing. At present, the shallow coal resources are nearly exhausted, and many coal mines have started to go deep mining, which can reach a mining depth of 800~1500m, with the increase of mining depth, gas emission is bound to increase, and the coal spontaneous combustion disaster more prominent. The symbiosis disaster of gas explosion and coal spontaneous combustion has become the common mode of major and extraordinarily serious accidents in coal mines. Cases of gas explosion caused by spontaneous combustion of coal are increasing$^{[1]}$.

Although research scholars have done a lot of work$^{[2-4]}$, the research on the three-dimensional simulation of coupled disasters needs some supplement. Especially in the process of coupled disasters, the reasonable ventilation, the location of the high-level pumping roadway, the determination of the extraction volume, the effect of the buried pipe extraction, etc., lack of relevant research. Therefore, this paper used the method of three-dimensional numerical simulation to study the gas flow field distribution law of gas concentration field and oxygen concentration field in goaf under different working conditions, and optimize key parameters such as high-level drainage roadway horizon and extraction quantity. It provides strong support for the compound disaster management of mines.

**Numerical Simulation Research**

**Overview of Mines and Working Faces**

The test face is located in the northwest wing mining area at an altitude of 534 above sea level. The length of the working face along the strike is about 1800m, the tendency length is about 240m, the average thickness is 6.4m. After appraisal by relevant national research institutions, there is no dust explosion risk in mining coal seams. The self-ignition tendency of coal seams is class II spontaneous combustion coal seams, and the working face adopts U-shaped ventilation mode, adopting long-wall comprehensive mechanized one-time mining full-height mining method, all slumping method to manage roof.
Establishment of Numerical Model

The numerical simulation model is established by the actual geometrical dimensions of the test face. As shown in figure 1, the length×width×height of the geometric model is 220m×200m×15m. The goaf is partially set as a porous medium space, and the inlet duct, the return airway and the coal mining face are all set as fluid spaces. The intake airway is set as the speed inlet, the outlet of the return airway is set as the free exit, the pressure difference between the two sides of the working face is -125Pa, the outlet of the high-level drainage roadway is set as the pressure outlet, the flow energy of the turbulent flow is set to 0.034J, and the dissipation rate is 0.003.

![Figure 1. Three-dimensional geometric model of the goaf.](image)

Influence of High-level Drainage Roadway on Gas and Spontaneous Combustion

**Three-Dimensional Distribution of Gas and Oxygen Concentration.** Figure 2 shows the three-dimensional distribution of gas and oxygen concentration fields in the goaf when the wind volume of the working face is 2000m³/min, the height of the mining roadway is 40m from the roof of the coal seam and the drainage mixing amount is 90m³/min. Due to the influence of drainage, the gas concentration near the horizon of the high-level drainage roadway is higher. The gas concentration in the high-level drainage roadway is greater than 24%, and the gas concentration at the outlet is stable at 32.3%, as shown in Figure 2 (a).

![Figure 2. Gas and oxygen concentration field when the high-level drainage roadway is 40m away from the roof of the coal seam.](image)

It can be seen from figure 2(b) that the contour of the oxygen concentration in the goaf of is parabolic. Oxygen concentration in the intake and return airway side is larger than in the central part of the goaf. This is because the central part of the goaf is easy to compact, the porosity is small, and the amount of air leaking into the central of the goaf is small. In the intake and return airways sides and in the middle of the goaf, the farthest distance between the boundary of the heat dissipation zone and the working face is 77.7m, 24.6m and 18.2m respectively. The range of oxidative heating zone is 25.9~112.4m, 24.6m~72.5m and 18.2~77.4m respectively in the intake, return airway side and in the central part of the goaf, especially on the side of the intake side. The range of the oxidation heating zone is up to 86.4m.
Influence of Construction Parameters of High-level Drainage Roadway on Gas and Spontaneous Combustion. Figure 4 shows the effect of gas drainage when the other parameters are kept unchanged, and only the height of the high-level drainage roadway is changed, and the statistics are compiled into Table 3. It can be seen that when the high-level drainage roadway is located 40m above the roof, the drainage concentration and scalar capacity of the high-level drainage roadway reach the maximum, which are 32.3% and 29.07m³/min respectively. However, the height of the high-level roadway is further increased. When it exceeds 40m, the surrounding cracks tend to close, the drainage resistance increases, and the drainage effect also decreases. Therefore, from the perspective of gas prevention and control, the high-level drainage roadway is most reasonably arranged 40m above the roof of the coal seam.
Figure 5 shows the oxygen concentration distribution in the goaf of the high-level drainage roadway at different levels. Compared with the distribution of spontaneous combustion three zones without drainage, it can be obtained that the wind speed of the goaf will increase as a whole, especially in the area close to the working face, the wind speed increase is more obvious. However, comparing (a), (b), (c), (d) in Figure 5, we can get: With the improvement of the drainage level of the high-level extraction roadway, the change of the contour with the wind speed of 0.24 m/min near the working surface area is small, the oxygen concentration of 8% contour increases with the elevation of the high-level drainage roadway, and gradually develops toward the deep of the goaf, so the corresponding oxidative heating zone width also gradually increases.

![Figure 5](image)

**Figure 5.** Oxygen concentration field when the high-level drainage roadway is at different levels from the roof.

When the high-level drainage roadway is located 20 m above the roof, the wind flow in the working face is affected by the pumping action and enters the high-level drainage roadway after passing through the shallow area of the working face. When the high-level drainage roadway is 30 m and 40 m above the top roof, the average width of the oxidation heating zone is 56.3 m and 61.1 m, respectively. When the high-level drainage roadway is 50 m away from the top roof, the maximum width of the oxidation heating zone is 105 m. The actual minimum daily advance of the working face is 2.47 m/d, the safety period of fire prevention in the goaf is 42.5 days, which is close to the natural ignition period of coal for 45 days, it is not conducive to fire prevention on the working face.

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t_s = \frac{l_{\text{max}}}{v} = \frac{86.4}{2.47} = 42.5
\]

Therefore, considering the two major disasters of gas and coal spontaneous combustion, the optimal layout of the high-level drainage roadway is 40 m above the roof.

**Conclusions**

In this paper, numerical simulation analysis is carried out on the effects of increasing air volume and various gas control measures on spontaneous combustion of gas and coal in goaf, and the following conclusion is drawn that when the high-level drainage roadway is used, only the height of the high-level drainage roadway is changed, and the remaining parameters are kept unchanged. With the increase of the arrangement position, the oxidative heating zone of the goaf gradually widens. When the high-level drainage roadway is arranged 40 m above the coal seam, the gas drainage effect is the best, the extraction concentration reaches 32.3%, the extraction pure volume is
29.07 m³/min, accounting for 69.71% of the total gushing amount, and can meet the need of spontaneous combustion protection.

Acknowledgments
This research was funded by National Key Research and Development Plan of China: 2016YFC0801804; Special Support Project of Science and Technology Innovation and Entrepreneurship Fund of Tiandi Technology: 2018-TD-MS017

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