Study on Distribution Law of Spontaneous Combustion "Three Zones" in Goaf of Fully Mechanized Mining Face with Large Mining Height

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Abstract: in order to explore the large mining height are broken coal seam fully mechanized working face goaf spontaneous combustion "three zones" under the different height of distribution, through the establishment of numerical model, builds the working face goaf spontaneous combustion "three zones" three-dimensional sampling analysis system, through the analysis of oxygen, carbon monoxide, carbon dioxide and other coal spontaneous combustion index gases change law of goaf spontaneous combustion dangerous area under different heights for the division, the goaf three-dimensional spontaneous combustion dangerous area is determined. The results show that the "spontaneous combustion zone" of goaf in fully mechanized coal face of large mining height gradually widens along the vertical height, and the spontaneous combustion risk area becomes larger.

1. Introduction
Goaf spontaneous combustion hazard zone division, commonly known as spontaneous combustion "three belt" division. The division of "three belts" was first proposed by polish scholars. From the perspective of natural combustion, goaf is divided into "three belts", namely, "scattered tropics", "spontaneous combustion zone" and "suffocation zone" [1]. In China, xu jingjun et al. [2] conducted quantitative analysis on the division of "three zones" in goaf, distinguished the concepts of oxidation heating zone and oxidation spontaneous combustion zone, and proposed the determination method of oxidation spontaneous combustion zone in goaf under dynamic conditions.

Through the observation tube or sensor embedded in the goaf, oxygen volume fraction distribution and air leakage intensity in the goaf are observed to determine the spontaneous combustion "three belts" in the goaf[3]. Fluent, Matlab and UDF adaptive software programming were used to simulate and verify the goaf's spontaneous combustion law under complex conditions such as non-homogeneous model, flow field distribution characteristics, regional distribution characteristics of goaf's self-combustion oxyde-heating, and coupling of spontaneous combustion and gas [4-5]. However, domestic field observation mostly USES horizontal buried sampling head sampling analysis, which cannot fully reflect the characteristics of the three-dimensional distribution of "three belts" of spontaneous combustion in goaf, resulting in a small division of the area of spontaneous combustion risk, and some neglect of fire prevention plan. Therefore, it is urgent to study the three-dimensional distribution law of "three belts" of spontaneous combustion in goaf.
2. Working face overview
Xiangyu coal mine 101 working face as the research object, the working face of large mining height are broken coal seam fully mechanized coal face, The coal seam is Class I self-burning coal seam, the shortest spontaneous combustion period is only 26 days, coal dust explosion hazard. Strike length is 1500m, dip length 300m. The coal seam thickness is 5-7.5m, with an average thickness of 6.5m. The dip Angle of the coal seam is 1° ~ 3°, and the average is 2°. Comprehensive mechanized coal mining technology of large mining height coal seam is adopted, and roof is controlled by caving method. In the process of advancing the working face, in order to ensure the advancing speed of fully mechanized mining working face, the bottom coal of 0.5m or so is left artificially in the working face floor.

3. Numerical simulation test

3.1 Establishment of numerical simulation geometric model
The geometric model was established by Gambit software, including an inlet roadway, return roadway, working face and goaf. Downhole equipment is ignored and each part is simplified into cuboids. The specific geometric dimensions are: 6 m wide, 4 m high and 10 m long; The working face is 8 m wide, 4 m high and 300 m long; The width of goaf is 300 m, including 20 m of stacking area, 60 m of loading area, 220 m of compaction area and 300 m of goaf length. The geometric model of goaf is shown in figure 1. The mesh size of the geometric model of goaf is 1 m, as showed in figure 2.

![Fig. 1 Goaf geometry model](image1)

![Fig. 2 Mesh generation of goaf geometric model](image2)

3.2 settings of boundary conditions
K-epsilon in the Laminar model is chosen for the calculation model, and the equation coefficient is the default value of the system. Wind inlet is set as velocity inlet, and velocity inlet parameters are wind speed, turbulence intensity and hydraulic diameter.

The hydraulic diameter is calculated as follows:

\[ D = \frac{4 A_q}{u} \]

Where, \( A_q \) is the cross-sectional area of the flow channel, m²; \( u \) is the wet cycle length, m.

The hydraulic diameter is 4.8 m.

The calculation formula of turbulence intensity is as follows:

\[ I = 0.16 \text{Re}^{-1/8} \]

The turbulence intensity is 2. 3%.

The inlet boundary is the velocity inlet, and the air inlet velocity is 1.53 m/s. The groups are divided into \( O_2 \) and \( N_2 \), with \( O_2 \) volume fraction of 21% and mass fraction of 23%. The volume fraction of \( N_2 \) was 79%, and the mass fraction was 77%. The export boundary is free export. The goaf was set as porous medium with porosity of 0, 24, 0, 18 and 0, 10 respectively.

In order to simplify the analysis and reflect the basic gas situation at the corner of the fully mechanized mining working face studied. The following assumptions are made: 1) air and gas in the simulation process are treated as incompressible gas and the flow is steady state without considering temperature change; 2) the goaf is set as a porous medium and divided into three zones. Only caving zone is set in the vertical direction, with different porosity but uniform distribution; 3) gas source items
are set in each area of goaf and distributed evenly; 4) the gas flow in coal and rock strata conforms to darcy's law, and the gas flow in goaf conforms to the turbulence model.

3.3 simulation analysis results
Simulation results of Fluent were imported into the post-processing software Tecplot, and the distribution cloud diagram of O$_2$ volume fraction in goaf was obtained, as shown in figure 3, and figure 4.

![Fig. 3 Distribution of O$_2$ volume fraction in the goaf area](image)

Fig. 4 Distribution of O$_2$ volume fraction in the goaf area

As can be seen from FIG. 3 and FIG. 4, the O$_2$ volume fraction in the goaf decreases gradually with the increase of the depth inside the goaf. The O$_2$ volume fraction in the air inlet roadway, return roadway and working face is about 20%, and gradually decreases as it penetrates into the goaf. According to the distribution shape of spontaneous combustion "three belts", the widths of the scattered tropics on the air inlet side, the middle of the working face and the return wind side are different, with the working face being the widest, the air inlet side second, and the return wind lane being the narrowest. The main reason is caused by different air leakage conditions in the goaf. The simulation results show that the width of spontaneous combustion band increases gradually in the vertical direction.

4. conclusion
1) the "spontaneous combustion zone" of goaf in fully mechanized coal face with large mining height gradually widens along the vertical direction.
2) according to the distribution law of residual coal in goaf, the gas sampling point should move up in the vertical direction during daily monitoring to ensure the accuracy of monitoring data.
3) based on the characteristics of "three zones" division in fully mechanized mining face of large mining height, when adopting grouting, nitrogen injection, three-phase foam injection and other fire-
fights technical measures, the height and scope of perfusion should be improved to ensure the reliability of fire-fighting measures.

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