Study on Spontaneous Combustion Law of Goaf in 31301 Working Face of Chahasu Coal Mine

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Abstract. Aiming at the serious problem of spontaneous combustion of coal seam in 31301 working face of ChahaSu Mine. Firstly, the industrial analysis of coal samples in the working face shows that the coal quality of the working face belongs to non-caking coal, which has the characteristics of low ignition point, high moisture content and no caking. By testing the marked gases of spontaneous combustion of coal samples, it is concluded that CO and C2H4 can be used as the representative gas of spontaneous combustion of coal oxidation to judge the spontaneous combustion of coal seams. According to the field monitoring data, the three-zone distribution of spontaneous combustion is calculated, and compared with the three-zone distribution of spontaneous combustion under the condition of fully closed simulation, the factors affecting the three-zone distribution of spontaneous combustion are obtained. Combining with the results of experimental analysis, the law of spontaneous combustion is studied and the reasonable advancing speed of working face is determined, which provides theoretical support for the formulation of enterprise fire prevention and extinguishing measures.

1. Introduction
For a long time to come, coal will still be the main energy source in the national economic development. [1].However, more than half of the mines in China are in danger of spontaneous combustion [2]. Mine fires seriously affect the safe production of coal mines. According to relevant statistics, the risk of spontaneous combustion in key coal mines accounts for more than half [3]. Coal spontaneous combustion not only destroys a large number of coal resources, but also endangers the safety of underground personnel, causes serious ecological environment pollution, and causes great damage to coal mining enterprises and the natural environment.

In recent years, with the development of coal mining technology, production efficiency has been significantly improved, but at the same time[4], the number of coal left over in goaf has increased, the air leakage is serious, and the risk of spontaneous combustion in coal seam has been aggravated. Chahasu Coal Mine has been puzzled by spontaneous combustion of coal seam for a long time, and the fire prevention measures taken have achieved certain results. With the development of working face, the law of spontaneous combustion in goaf needs further study. Taking the 31301 working face of Chahasu Coal Mine as the research object, the author carries out the related technology research of fire prevention and extinguishing, and formulates the technical measures of fire prevention and extinguishing suitable for the mine, so as to achieve the goal of comprehensive control of mine spontaneous combustion fire.

2. Spontaneous Combustion Mechanism of Coal
Coal spontaneous combustion refers to the phenomenon that when coal with spontaneous combustion tendency encounters oxygen, it produces heat through oxidation reaction and burns after the coal
temperature rises to the ignition point through heat accumulation[5]. The spontaneous combustion of coal left over from goaf can occur only when there is enough oxygen and a certain amount of heat.

The necessary conditions for spontaneous combustion of coal can be summarized as follows:

1) Coal with spontaneous combustion tendency exists in a broken state, that is, low temperature oxidation.

2) Adequate ventilation and oxygen supply. Oxygen concentration is maintained at a relatively high level due to ventilation, so that there is enough oxygen in the goaf and the residual coal will be oxidized, thus accelerating the oxidation of coal.

3) The gas flow rate is maintained in a steady state, which can provide enough oxygen without taking away a lot of heat.

4) When the above conditions occur at the same time, and the duration is longer than the spontaneous combustion period of coal. The spontaneous combustion of different coal seams is different, and the conditions of oxygen supply, heat storage and heat sink of each coal seam are different, finally, the spontaneous combustion of each coal seam is different naturally. Therefore, spontaneous combustion of coal is caused by the combination of oxidation of coal itself and external conditions. In addition, the advancing speed of the working face is also an important factor of the spontaneous combustion of the coal left over from the goaf.

3. Study on Basic Parameters of Coal Spontaneous Combustion Characteristics

3.1 Industrial Analysis of Coal

According to the national standard GB/T 474-2008, the basic parameters of moisture, volatile matter, ash and fixed carbon in coal samples are determined by experiments[6]. From this, the content of organic matter in coal can be judged, and the combustion characteristics of coal samples, as well as the calorific value, the type of coal, the effect of processing and utilization and industrial use can be obtained.

In this experiment, TGA-2000 full-automatic industrial analyzer was used. Firstly, the temperature was controlled at about 100 (°C) to measure the moisture content in coal samples. Then nitrogen was injected into the instrument, and the temperature was raised to 500 (°C). The volatile content was calculated by weighing the coal samples. The ash content in coal samples can be measured by increasing the temperature to 1000 (°C). The device can automatically place and move the crucible lid by moving up or down the upper sample tray used to place the crucible lid, effectively avoiding sample oxidation and increasing the accuracy of measurement results. The measured data are shown in Table 1.

| Experimental coal sample | Moisture | Volat | Ash   | Fixed Carbon |
|--------------------------|---------|-------|-------|--------------|
| 31301 coal sample        | 10.134% | 30.482% | 2.836% | 56.548%      |

The experimental results show that the volatile matter of coal in Chahasu 31301 working face is relatively high, which indicates that the coal has low metamorphism and will emit more volatile gases and generate more heat when burning. Compared with other kinds of coal, the ash content of this kind of coal is very low, which indicates that the proportion of non-combustible substances in this coal is very low, and the combustion of coal of unit mass will emit more heat. It also shows that Chahasu coal seam has a higher tendency of spontaneous combustion. Comparing with the national standard GB/T 5751-2009 for coal classification in China, the coal samples are non-sticking coal with low ignition point, high moisture content and no cohesion[7].

3.2 Choice Representative Gas

By simulating the temperature change and environmental conditions of coal spontaneous combustion, the gas and its concentration change with the increase of temperature were measured in this experiment. The parameters of critical temperature and concentration of different gases were recorded,
and the spontaneous combustion characteristics of coal were obtained comprehensively. The experimental process is as follows:

1) Choosing coal samples from 31301 working face of Chaha Su Mine and crushing them in air by natural drop hammer method, screening coal samples with particle size of 1.25-3.0 mm. During the experiment, the air flow rate was set at 100 mL/min and the heating rate was 1 °C /min.

2) Air compressor sends air through pipeline to coal spontaneous combustion simulator. It is heated first and then enters from coal sample tank, warms coal sample, and then flows out from the top.

3) The gas is extracted by the bundle tube monitoring system under the control of a computer and sent to a gas chromatograph to determine the contents of possible gases such as CO₂, CO, CH₄, C₂H₆, C₂H₄, C₂H₂, N₂, O₂, and to automatically store the results.

![Coal spontaneous ignition simulation device](image)

**Figure 1.** An experimental device for the generation of gases during low temperature oxidation of coal

![Curve Chart of CO Concentration Change with Coal Temperature](image)

**Figure 2.** Curve Chart of CO Concentration Change with Coal Temperature
Figure 3. Curve Chart of C$_2$H$_4$ Concentration Change with Coal Temperature

According to Figure 2, the concentration of CO varies slightly between 20 and 100 (°C), indicating that coal is slowly oxidized at low temperature, and the concentration begins to increase significantly at 100 (°C). At this temperature, coal begins to accelerate oxidation, and then gradually tends to be stable. Therefore, CO concentration changes slowly with temperature, then accelerates and then stabilizes. There are obvious regular changes, so CO can be used as a marker gas to detect spontaneous combustion of coal oxidation.

According to Fig. 3, C$_2$H$_4$ begins to appear at 120 (°C), and the concentration increases with the increase of temperature at 150 (°C). It was found that the temperature of C$_2$H$_4$ coal has reached at least 120 (°C), and if the concentration changes rapidly, it has reached more than 150 (°C). C$_2$H$_4$ can be selected as the landmark gas.

The experiment also tested the concentration change of CO$_2$ and C$_2$H$_6$, which also showed certain regularity with temperature change, but because CO$_2$ was susceptible to the influence of external conditions, it was not a reliable landmark gas; C$_2$H$_6$ at 120 (°C) began to appear, the concentration change in the early stage was very small, the change in the later stage was only regular when the coal accelerated oxidation, but neither of them was suitable for comparison. Significant gases.

4. Division of "Three Zones" of Spontaneous Combustion in 31301 Working Face of Chaha Su Mine

4.1 General Situation of 31301 Working Face
31301 working face is the first mining face of the mine, the main mining coal seam, the strike length of the coal seam is 2503.74m, the width is 300.58m, the average thickness of the coal seam is 6.015m; the residual thickness of the goaf is 1-1.5m, the overall change of the thickness of the coal seam is small, the structure is relatively simple, and it belongs to the stable and relatively stable coal seam. The working face is located in the west of 31 mining area, the southwest is 31301 working face return air transport channel, the northeast is 31301 working face equipment train channel, the northwest is well bottom yard, and the Southeast 68m is 31031 equipment train channel transport measures joint lane. The strike length is 2300m, the width is 260m, and the working face area is 752573.

4.2 Actual Measurement “Three Zones “of Spontaneous Combustion in Goaf

| Basis for division | Cooling zone | Oxidation zone | Asphyxia zone |
|-------------------|--------------|----------------|---------------|
| Oxygen concentration % | C (O$_2$)$\geq$18 | 10$\leq$C (O$_2$)$<18$ | C (O$_2$)$<10$ |
| Air leakage velocity /m*min$^{-1}$ | V$\geq$0.24 | 0.10$\leq$V$<0.24$ | V$<0.10$ |
The concentration of oxygen was used as the basis for classification. 31301 working face adopts "U" type ventilation, the air supply capacity of working face is about 2200 m³/min. Drilling holes in the coal pillars along the grooves on both sides of the working face, then introducing the adopted gas into the gas chromatograph through the gas production bundle tube, the variation of oxygen concentration in the goaf with the advancing distance of the working face is analyzed. Fig. 4 is drawn from the measured data.

![Figure 4. Change Chart of Oxygen Concentration in Goaf of 31301 Working Face](image)

According to the results of the drawing analysis and the three zones division, according to the table comparison, the area behind the working face is divided into heat dissipation zone within 178 m, spontaneous combustion zone between 178 m and 224 m, and asphyxiation zone after 224 m.

### 4.3. Numerical Simulation in Closed Case

In order to compare the spontaneous combustion three-band distribution with the measured conditions, and to analyze the effective method for preventing the spontaneous combustion of the residual coal in the goaf, this paper simulates the distribution of the three belts under the ideal state of closed and closed airtight enclosure. The specific parameters of the numerical simulation, the working face length is 280m, the width is 4.38m, the height is 5.2m, the length of the goaf is 260m, the length of the inlet duct is 35m, the width is 5.5m, the length of the return duct is 35m, and the width is 5m. The simulation results are shown in Figure 5.

![Figure 5. Numerical simulation of the three-band distribution of spontaneous combustion in goaf](image)
The simulation results show that when the contact roadway of the working face is tightly closed, the oxygen concentration on both sides of the goaf increases, as the air leakage increases, the width of the spontaneous combustion zone increases, and the width of the heat dissipation zone also increases; therefore, the oxygen environment is provided for coal spontaneous combustion. The risk of spontaneous combustion of coal is increased. Therefore, timely sealing of the roadway and keeping the airtight and tightly closed is conducive to the prevention and control of spontaneous combustion in the goaf, and also provides a basic guarantee for taking other fire prevention measures.

4.4 Work Surface Advancement Speed

The speed of the working face has an important impact on the spontaneous combustion of the coal seam. If the propulsion speed is too slow, there will be a higher risk of spontaneous combustion in the spontaneous combustion zone of the goaf than the natural ignition period of the coal [8]. According to the previous data, the shortest natural ignition period of the 31301 working face of Chahasu Mine is 37 days. The relationship between the recovery speed and the shortest spontaneous ignition period of the spontaneous combustion zone is as follows:

$$V_C = \frac{L_1 + L_2}{T}$$

(1)

$V_C$ recovery speed, $L_1$ heat dissipation belt width, $L_2$ spontaneous combustion belt width, $T$ shortest natural ignition period. According to the above data, the length of the heat dissipation tape and the length of the self-ignition zone are 224m. The safe recovery speed is calculated to be 5.25m/d.

5. Conclusion

(1) 31301 working face coal is non-coking coal, the degree of coalification is low, the burning point is low, a large amount of volatile gas is generated during combustion, and it has a high spontaneous combustion tendency and can be used as thermal coal or civil fuel.

(2) CO and C$_2$H$_4$ can be used as index gases for judging the natural ignition of coal.

(3) Real-time monitoring of gas changes in the goaf behind the working face and dividing the self-ignition “three belts” behind the 31301 working face of Chahasu Coal Mine according to the actual measured data. The range within 178m behind the working surface is the heat dissipation belt. The area after 266m behind the working surface is a suffocation zone; the area between the two is a spontaneous combustion zone, and the width of the spontaneous combustion zone is 58m.

(4) Through the Fluent software, the oxygen concentration in the goaf is completely sealed, and the closed loop air leakage causes the spontaneous combustion zone to increase, the oxygen concentration increases and enters the deep part of the goaf, providing oxygen environment for coal spontaneous combustion. The risk factor for spontaneous combustion.

(5) Closing the lanes in time and keeping them tightly closed, which is conducive to the prevention and control of spontaneous combustion in the goaf, and also provides a basic guarantee for taking other fire prevention measures.

(6) Safe production can be guaranteed when the working surface propulsion speed is greater than 5.25m/d.

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7. References

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