Control technique of spontaneous combustion in fully mechanized stope during period of end caving under complex mining influence

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Abstract. In view of the phenomenon of spontaneous combustion of coal seam occurring during the period of end caving under complex mining conditions, taking the 1116 (3) stope of Guqiao mine as the object of study, the causes of spontaneous combustion during the period of end caving are analyzed, according to the specific geological conditions of the stope to develop corresponding fire prevention measures, including the reduction of air supply and air leakage in goaf, reduce the amount of coal left, reasonable drainage, nitrogen injection for spontaneous combustion prevention, grouting for spontaneous combustion prevention and permanent closure, fundamentally eliminates the potential for spontaneous combustion during the period of 1116(3) stope end caving. The engineering practice shows that this kind of measure has reference value for the prevention and control of spontaneous combustion during the period of stope end caving.

1. Geological survey of mine and test area

1116 (3) stope is sixth blocks of the northern N0.1 13-1 seam rise entry panel of Gu Qiao mine, the inclined longwall comprehensive mechanized mining method is adopted in this block, during the mining period, the stope is fully mined along the 13-1 seam roof. The strike length of the 1116(3) stopes was 2816.2m, the inclined length was 231.3m, the average thickness of the coal seam was 4m. 1115 (3) stope and 1117 (3) stope are close to 1116 (3) stope, and 1116 (1) stope of 11-2 coal seam is located below 1116 (3) stope, all of them have been finished and closed, the spatial relationship between the 1116 (3) stope and the surrounding stope is shown in Figure 1. As of December 1, 2014, the working face has been extracted to 2557.5m at the haulage gate point and 2565.5m at the track gate roadway. It is expected to end caving at the 2760m position.

As the stope is affected by the adjacent mining, the surrounding rock cracks around the roadway are relatively developed, and there is a serious air leakage phenomenon. During the period of end caving, it is easy to cause spontaneous combustion. Taking 1116 (3) stope as the object of study, this paper studies control technique of spontaneous combustion during period of fully mechanized mining face end caving under complex mining influence.
2. Analysis of the cause of combustion in test area

13-1 coal seam are mainly mining in 1116 (3) stope, coal quality test results show that the coal seam has a strong low temperature oxidation characteristic, belongs to spontaneous combustion seam. Haulage gate and track gate roadway of the stope are used for driving along goaf, there are many high-risk spots in the mining process, and the partial deformation of the protective pillar of haulage gate and track gate roadway is serious, these increase the possibility of spontaneous combustion in the coal seam. In addition, 1116 (3) stope is affected by the mining influence of 1116 (1) stope. The deformation of the roadway is serious, and the hidden danger of air leakage is increased.

Field measurement shows that the gas emission of 1116 (3) stope is 7~10m$^3$/min, and the amount of ventilation air methane after pumping is 4m$^3$/min, and the air volume during normal mining stage is 1825m$^3$/min. The excessive air flow will cause air leakage in the goaf, providing the natural conditions for the continuous oxygen supply in the goaf, and the potential danger of spontaneous combustion in the stope end caving stage, so the fire prevention measures should be taken.

3. Spontaneous combustion control technology used in test stope

3.1. Reduction of air supply and air leakage in goaf

During the period of end caving, the air supply shall be reasonably reduced after meeting the demand for continuous oxygen supply. Reducing the air supply volume and reducing the air pressure at the upper end and the lower end are helpful to reduce the air leakage in the goaf. In accordance with the amount of gas emission at that time, a reasonable reduction in air volume will play a very good role in control of spontaneous combustion. Carry out continuous filling in the upper corner and lower corner ahead of schedule 50m, and it needs to ensure tight filling and small amount of air leakage. The coal gangue is loaded into a special anti-woven bag for coal mine, it is used for filling and compacting the area where air leakage may occur, so as to reduce the air leakage in the goaf.

3.2. Reduce the amount of coal left and reasonable drainage

An important reason is that the coal spontaneous combustion of coal itself, during the stope end caving, at the 60m ahead of the stopping line, the working face is mined with the roof, the floating coal in the two roadways of stope should be cleaned up in time. It plays an important role in fire prevention and control. During the end caving and closed of stope, in accordance with the trend of gas change, 1116 (3) top corner buried pipe and high-level suction roadway and bed plate tunnel will be controlled or stopped in time. Prevention of over mining leads to negative pressure in goaf and prevents spontaneous combustion hazard.

3.3. Nitrogen injection for spontaneous combustion prevention

Based on the inert nature of nitrogen and the oxidation mechanism of coal, nitrogen is injected into goaf and residual coal belt to seep into goaf, caving zone, fracture zone and residual coal zone. The oxygen content of these areas is reduced to form a nitrogen inert zone. There is a nitrogen injection pipeline in haulage gate of 1116 (3) stope, start the nitrogen injection tube at the distance of 40m from the end caving line, the end of the nitrogen injection tube starts at the outer 10m and adds tee every...
10m to draw the nitrogen. The nitrogen concentration produced by the nitrogen generator is higher than 97% and can achieve good results.

3.4. Grouting for spontaneous combustion prevention

A grouting pipe for daily goaf grouting is installed in track gate roadway of 1116 (3) stope, in order to strengthen grouting effect, the grouting pipe will be transformed into three-way pipe grouting during the period of end caving. Three-way grouting pipes are buried in front of 80m, 60m and 40m at the distance from track gate roadway of 1116 (3) stope to the end caving, and at the end of three pipelines increased a flower tube (as shown in Figure 2).

Construction drilling for spontaneous combustion prevention: Designed to construct a fire drill site in the track gate roadway of 1116 (3) stope, spontaneous combustion prevention drilling constructed by pumping team (as shown in Figure 3).

![Figure 2. Layout of pipeline for spontaneous combustion prevention in 1116 (3) stope](image)

![Figure 3. Design of drilling for spontaneous combustion prevention in 1116 (3) stope](image)

3.5. Permanent closure

After the support is removed, and a double resistant woven bag (filling the gangue) is used for temporary closure in the upper end of the stope and the lower end of the stope. Then strengthen the roadway support within the 10m range of the permanent closure wall, and grouting treatment is carried out to prevent leakage around the permanent closure wall.

To strengthen the roof support on both sides of the closure wall, a wooden pile is arranged at both sides of the closure wall, and the wood pile relates to the roof. The quality of the closure wall has a direct influence on the closure effect. In the construction of the closure wall, the cutting depth of the top, bottom and two sides of the roadway are 300mm, 1000m and 1000mm respectively, so as to ensure that they are fully embedded in the roadway, so as to achieve a good isolation effect. The
clos
[89x718]ure wall of the stope adopts double wall structure, the wall thickness is 0.8m, and the two walls are spaced 1.4m. The steel cage is placed between the two walls, and with cement mortar and other fire extinguishing materials with pressure grouting (as shown in Figure 3). The closure wall of this specification, not only can play the role of fire in isolation, but also has strong anti-impact ability. To better understand the gas, carbon monoxide and other gases in the closure area, a pipeline is reserved as the observation tube on the closure wall, and a two-way drain pipe is provided for closure area drainage.

4. Test of spontaneous combustion prevention effect
The implementation of various spontaneous combustion prevention techniques during the end caving period of 1116 (3) stope, and achieved a smooth end caving of the 1116 (3) stope. Through the grouting of the goaf and nitrogen injection, the spontaneous combustion prevention in the goaf can be prevented and controlled well. Through the examination of the closure wall and the sampling of the goaf, there is no CO in closure area, and the gas concentration is at the normal level, and the spontaneous combustion prevention technology plays a better role, as shown in Table 1.

Table 1. Comparison of CO content before and after implementation of spontaneous combustion prevention technology.

| Support number | 96 | 95 | 94 | 93 | 92 | 91 | 90 | 89 | 88 |
|----------------|----|----|----|----|----|----|----|----|----|
| Before the measures are implemented | 12 | 8  | 5  | 11 | 9  | 4  | 5  | 2  | 7  |
| After the measures are implemented  | 0  | 0  | 0  | 2  | 1  | 0  | 0  | 0  | 0  |

5. Conclusion
This paper takes Guqiao Mine 1116 (3) stope as the research object, analyzes the characteristics of mining layout and mining influence of adjacent stope. It can be seen that the surface has increased the hidden danger of air leakage under the condition of complex mining influence, and it can easily cause spontaneous combustion of coal seam.

According to the specific geological conditions of the 1116 (3) stope, the main technical measures for spontaneous combustion prevention during the period of end caving are explored.

Field spontaneous combustion prevention practice shows that the goaf closed effect is good. The grouting of the goaf and nitrogen injection play an important role in the prevention and control of spontaneous combustion during the working face.

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