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Research on the Occurrence Regularity and Influencing Factors of Coal and Gas Outburst

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Abstract: In order to explore the occurrence regularity of coal and gas outburst accidents in Yongshan coal mine and ensure the daily safe and efficient production of coal mines, based on the gas geological data of Yongshan coal mine and the coal and gas outburst accidents that have occurred in the mine over the years, the main characteristics of outburst accidents are statistically analyzed, and the influence of factors such as roof and floor lithology, faults and structures on outburst are discussed. The results show that the outburst strength of Yongshan mine is not large, mainly medium and small outbursts, and the outburst strength increases with the increase of coal seam depth. The outburst is likely to occur at the hanging wall and annihilation end of reverse faults, and fault structure is the main influencing factor leading to the outburst of Yongshan mine. And it is necessary to strengthen the exploration of fault structures in Yongshan mine and the targeted extraction of gas in structural belts.
Keywords Coal mine, Coal and gas outburst, Regularity of occurrence, Main influencing factors, Fault structure

INTRODUCTION

Coal and gas outburst is an extremely complex gas dynamic phenomenon encountered in the production of underground coal mines which can suddenly throw a large amount of crushed coal from the coal body to the roadway or stope in a very short time, and gush out a lot of gas [Hu, et. al., 2013 and Li, et. al., 2010]. Since the world's first recorded coal and gas outburst accident occurred in the Loire coal field in France in 1834 in the Isaac coal mine, more than 20 countries and regions have had coal and gas outburst accidents. The first outburst accident occurred at the Fuguo mine of the Liaoyuan mining bureau on April 20, 2005. At present, scholars at home and abroad have unified their understanding of coal and gas outburst mechanism into the "comprehensive action hypothesis" [Liu, et. al., 2018 and Peng, et. al., 2016], and believe that it is a gas dynamic phenomenon generated under the combined effects of ground stress, gas, and coal structure. These three factors are controlled by geological structure [Shu, et. al., 2018, Wei, et. al., 2020, Xu, 2018 and Yang, et. al., 2019].

The coal mines in Jiangxi Province have complex geological conditions, many steep coal seams, heavy disasters, large numbers, and small production scale, and the average single well output is less than 50,000 tons/year [Chen, et. al., 2020, Liu, 2012 and Shan, 2016]. In recent years, coal and gas outburst accidents have occurred from time to time. For example, on April 20, 2010, a major coal and gas outburst accident occurred in Xingfeng mine of Xingmin coal mine. On September 30, 2013, a coal and gas outburst accident occurred in the second mining area of Qujiang coal mine. On February 28, 2015, a large coal and gas outburst occurred in Yongshan coal mine of Leping mining bureau. Therefore, sufficient attention must be paid to coal and gas outbursts in coal mines in Jiangxi Province. At the same time, the geological conditions of Yongshan mine are very complicated, and it is one of the mines with the most serious gas outbursts in Jiangxi Province. Since the mine was built, a total of 98 coal and gas outbursts have occurred [Chen, et. al., 2003, Liao, et. al., 1994, Yu, et. al., 2013 and Zhang, 2011].

Yongshan mine is located at the southwestern end of the Yongshan mine in Leping, Jiangxi. The regional structure is connected to an anticline, with long folds parallel to each other, and the direction of the structure line is N40~60^{o}E. Because the northwest side was destroyed by the F8 strike reverse fault, the minefield became a "steeply inclined" monoclinic structure inclined to the northwest. The coal seams of the Late Triassic Anyuan Formation were mined in the mine. There are 13 mineable layers, and the total mineable thickness is 18.61m. Among them, the second, third, fourth, fifth, and sixth coal seams are the main mining seams. The thickness of the coal seams varies greatly. Mainly siltstone, main floor is mudstone, and coal type is anthracite. Therefore, based on the example of outburst in the main coal seam of Yongshan mine, the author analyzes the rules and influencing factors of coal and gas outburst accidents in this mine, and finds out the main influencing factors that lead to coal and gas outbursts, so as to contribute to the safety and production of the coal mine and provide technical support for gas prevention and control work.

REGULARITY AND CHARACTERISTICS OF COAL AND GAS OUTBURST

The Yongshan mine was identified as a coal and gas outburst mine. As of 2017, the mine had 98 outbursts and 72 outbursts in the main coal seam (as shown in Table 1). It is one of the most serious coal and gas outbursts in Jiangxi Province.

Table 1 Statistics of coal and gas outburst in the main coal seam

Main coal seam	Coal thickness(m)	Coal seam dip(°)	Number of outburst	Average outburst strength(t)
2	1.65	62~88	5	51
3	3.31	65~88	17	46.8
4	0.91	65~88	22	239.8
5	1.24~7.33	60~78	15	262.7
6	2.30	60~76	13	348

2.1 General characteristics of coal and gas outburst

(1) There are more small-sized protrusions, but less large and medium-sized protrusions.

According to the amount of outburst coal, outbursts are classified into four categories: extra large, large, medium, and small for statistics (as shown in Table 2). ① Extra-large outbursts with outburst coal ≥1000 tons/time occurred 4 times. ②Large outbursts with outburst coal amount 500 to <1000 tons/time occurred 0 occurrences. ③Medium-sized outbursts with outburst coal amount 100 to <500 tons/time occurred 15 times. ④Small outbursts with outburst coal volume <100 tons/time occurred 53 times.

Table 2 Classification by the amount of outburst coal

Classification	Outburst coal(tons/time)	Number of outburst
Extra large	≥1000	4
Large	500 ~ 1000	0
Medium	100 ~ 500	15
Small	<100	53

(2) Outburst is the main priority, and pressing out and pouring out are supplementary.

Among the 72 outbursts that occurred in the main coal seam of Yongshan coal mine (as shown in Figure 1), 18 pour out, accounting for 25% of the total outbursts. 15 press out, accounting for 21%. 39 typical outbursts, accounting for 54%.

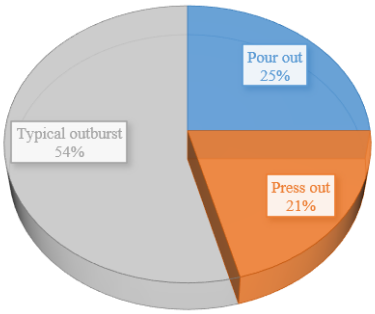

Figure 1. Distribution of accident types

(3) Outburst is likely to occur in the fault zone.

According to statistics, 52 outbursts occurred in the area of stress concentration near the fault, accounting for 72.2% of the total outbursts. In the process of roadway excavation, small faults are also prone to outbursts. The data shows that there are 9 outbursts near the F52 fault in the 26 mining area. It is as shown in Table 3.

Table 3 Statistics of the relationship between faults and salient points

Fault number	Fault properties	Towards	Dip (°)	Drop distance (m)	Frequency
F5	Reverse fault	E65°S	75~80	50	11
F24-25	Reverse fault	NE	80~83	160	7
F26	Reverse fault	N60~80°E	72~83	50	12
F29	Reverse fault	W45~66°S	85	150	13
F52	Reverse fault	E58°S	74	10	9

(4) The outburst strength increases as the depth of the coal seam increases.

There are 35 outbursts in the area with a depth of 100~200m, with an average outburst strength of 135.1t. There are 28 outbursts occurred in the area with a buried depth of 200~300m, with an average outburst strength of 209.6t. Four outbursts occur in the buried depth of 300~400m, with an average outburst strength of 292t. Five outbursts occur in the buried depth of 400~500m, with an average outburst strength of 608.6t. It is as shown in Table 4.

Table 4 Statistics of outburst accident characteristics by buried depth

Buried depth(m)	Number of outburst	Average outburst strength(t)
100~200	35	135.1
200~300	28	209.6
300~400	4	292
400~500	5	608.6

2.2 The salient features of coal and gas outburst

(1) The characteristics of coal and gas outburst in Yongshan mine are very obvious.

The salient points are concentrated in the fault action area and the stress concentration area, with obvious zoning characteristics. The strong fracture zone and in-situ stress concentration area formed by the influence of folds and faults are mostly distributed. It can be seen that the geological structure controls the distribution of prominent points.

(2) The hanging wall and end of reverse faults are prone to outburst.

There are many reverse faults in the Yongshan minefield. A total of 52 outbursts occurred near the reverse faults, including 32 on the hanging wall and 15 on the end. Take the F26 reverse fault in the 22 mining area of Yongshan mine as an example, among the 12 outbursts that occurred nearby, the hanging wall occurred 8 times and the end occurred 4 times.

ANALYSIS OF INFLUENCING FACTORS OF COAL AND GAS OUTBURST

Through the outburst analysis, it is found that the factors affecting the outburst are:

(1) The influence of roof and floor lithology and coal seam dip on outburst

The coal measures of the Late Triassic Anyuan Formation have a thickness of 300~1000m, and contain multiple layers of mudstone and siltstone. The roof and floor of each coal seam are basically similar. The floor is dominated by mudstone and the roof is dominated by siltstone. Poor air permeability creates good conditions for gas storage. In addition, the inclination angle of the coal seam also has a certain influence on the outburst. Since the inclination angle of the coal seam is between 60~88o, the gravity stress of the coal body increases the outburst power.

(2) Control of faults on protrusion

The distribution of outbursts in Yongshan mine is closely related to the distribution of faults. The high-angle, compressive and torsional reverse faults in the minefield are extremely developed. The fractures caused by the compression stress generally have strong sealing properties, making the coal seam and its surrounding rock more dense, the ground stress more concentrated, and the coal body structure is seriously damaged. It is conducive to the accumulation of gas, which leads to frequent coal and gas outbursts near faults. In addition, coal and gas outbursts mostly occur near reverse faults, accounting for 72.2% of the total outbursts, especially at the hanging wall and end of faults. It can be seen that the compression-torsion reverse fault has a control effect on the coal and gas outburst of Yongshan mine.

(3) Influence of structural coal on outburst

The geological structure of Yongshan mine is complex, the coal seam is subjected to strong compression and shear deformation, and the coal body is seriously damaged. Type III and IV structural coals are generally developed, and local layers are developed. A large number of measurement tests have shown that the outburst coal seam of Yongshan mine is soft and has poor permeability, and the coal firmness coefficient f value is 0.13~2.61, generally less than 0.5. In addition, coal analysis speed is fast, and the initial gas emission speed of coal $\triangle P$ is 5~30, generally greater than 16. Coal has strong gas adsorption capacity and high gas content. It can be seen that the development degree of structural coal has an important influence on coal and gas outburst.

According to the above analysis, the coal in Yongshan minefield has a high degree of coal metamorphism and a large amount of gas generation. In addition, the poor air permeability of the roof and floor is not conducive to the escape of gas. This results in a high gas content in the coal seam of Yongshan mine, creating a precondition for outburst. Compression and torsion reverse faults are very developed inside the minefield, and the in-situ stress in the fault zone and its affected area is very concentrated, which is an important factor leading to coal and gas outburst. Such in-situ stress causes a high degree of closure of fractures and fissures, which is conducive to the accumulation of high-pressure gas, and the coal body is severely damaged by squeezing and shearing, and forms a tectonic coal with strong adsorption capacity and low structural strength, creating a necessary condition for outburst. According to the above analysis, the fault structure controls the three factors of coal and gas outburst (earth stress, gas, coal body structure). Therefore, fault structure is the main controlling factor for coal and gas outburst in Yongshan mine.

CONCLUSION

(1) The outburst of Yongshan mine has many small outbursts, outbursts are prone to occur in the fault zone, and the outburst strength increases with the increase of coal seam depth. The distribution of coal and gas outbursts has obvious zoning characteristics and is largely controlled by geological structures; outbursts mostly occur on the hanging wall and end of reverse faults.

(2) Fault structure is the main controlling factor of coal and gas outburst in Yongshan mine. The internal pressure torsion reverse fault in Yongshan minefield is very developed, and the in-situ stress in the fault zone and the affected area is relatively concentrated. Due to the shear failure of faults, tectonic coals with strong adsorption capacity and low coal strength are formed, creating necessary conditions for coal and gas outbursts. Compression-torsion faults have good sealing properties and are conducive to the accumulation of high-pressure gas.

(3) In the future mining process, it is necessary to strengthen the exploration of fault structures in Yongshan mine and the targeted extraction of gas in structural belts.

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