Analysis of Coal Seam Gas Emission Based on Mine Gas Drainage Statistics

Jufeng Zhang 1, *, Xuguang Li 2, Fengfeng Yang 1, Tai Xu 1, Chao Zheng 1, Zaiquan Miao 3 and Jianjiang Zhang 3

1 School of Energy Engineering, Longdong University; Qingyang 745000, China
2 China Railway 19th Bureau Group First Engineering Co., Ltd., Liaoyang 111000, China
3 Weijiadi Coal Mine Jingyuan Coal and Electricity Co., Ltd. Baiyin 730913, China

*Corresponding author e-mail: 422622510@qq.com

Abstract. The statistics and analysis of mine gas extraction is very important for mine gas control, which provides a basis for the formulation of mine gas extraction plan. Because of its simple and convenient characteristics, it is favored by the engineering and technical personnel in the coal mine field, and has been widely used, and achieved good results. Based on the statistics of gas drainage in Weijiadi Coal Mine from 2008 to 2018, the characteristics and quantity of gas emission are analyzed according to the statistical results of gas drainage in Weijiadi Coal Mine, and the characteristics of gas emission in the process of driving in the main mining seam are predicted, and the mathematics relations of the length of driving roadway and the quantity of gas emission is obtained.

1. Introduction

In order to scientifically and rationally formulate gas control measures and mine air volume allocation, it is necessary to accurately predict mine gas emission and conduct gas emission analysis. The Standard of Safety Production Industry of the People's Republic of China "Prediction Method of Mine Gas Emission" (AQ1018-2006) stipulates that separate source prediction method and mine statistics method are used to predict and analyze mine gas emission [1]. Through the statistical analysis of the gas drainage volume over the years, we can predict the gas emission situation in the next few years, which is conducive to the formulation and implementation of the mine gas control plan.

Scholars at home and abroad have used a variety of methods and models combined with mine statistics to predict mine gas emission. Liu Yang [2] calculated the gas emission from the adjacent 12 # coal seam in Nanzhuang Coal Mine by combining mine statistics and source separation prediction methods. Zhang Wendong [3] used the prediction model based on Support Vector Regression (SVR) to predict the mine gas emission. Xiaodan [4] drew the fault tree of the factors causing errors of mine statistics method and source separation prediction method, by combining with the actual situation of the site, and puts forward the corresponding measures to improve the prediction accuracy of gas emission. He Qing [5] improved the measuring technology of basic data such as gas content, a prediction method considering the main control factors affecting gas emission and their coupling relationship synthetically is established, which improves the prediction accuracy of coal seam gas emission. These research results
provide a basis for mine statistical method to predict coal seam gas emission. This paper mainly applies mine statistical method to analyze gas emission and gas emission characteristics of main coal seam in Weijiadi Coal Mine, and provides a basis for formulating practical gas prevention and control measures.

2. Mine profile
Weijiadi Coal Mine is located in Gansu Province, China. The minefield is part of Baojishan Coalfield in Jingyuan Mining Area. The coal-bearing strata in the minefield are Middle-Lower Jurassic, which contain five seams of coal. From top to bottom, there are NO.1-no coal seam, NO.1 coal seam, NO.2-no coal seam, NO.2 coal seams, and NO.3 coal seams. The mineable coal seam is NO.1 coal seam, NO.2 coal seam and NO.3 coal seam, and the main coal seam is NO.1 or NO.3 coal seams. The average total thickness of the main coal-bearing strata is 88.28 m and the coal-bearing coefficient is 27.5. The mineable coal seams are concentrated in the middle and lower Jurassic, with a total thickness of 22.5 m. The NO.1 coal seam is located at the top of the Middle and Lower Jurassic, the NO.2 coal seam is located below the NO.1 coal seam, and the NO.3 coal seam is located at the bottom of the Middle and Lower Jurassic, just above the bottom conglomerate.

3. Statistics and Analysis of Mine Gas Drainage Quantity

3.1. Statistics of Coal Seam Gas Drainage
Before 2004, gas extraction in coal mines mainly focused on drilling through seam floor, supplemented by drilling along seam and roadway extraction. After 2004, the main method of mine drainage is along-seam borehole extraction, supplemented by through-seam borehole extraction of coal seam floor. In 2012, large diameter surface drilling was carried out for gas extraction in the mine, and good results were achieved. Mine gas drainage over the years is shown in Table 1.

| Particular year | Drainage in the same year (10^4 m³) | Cumulative extraction (10^4 m³) |
|-----------------|-------------------------------------|-------------------------------|
| 2008            | 1198.89                             | 10035.19                      |
| 2009            | 1807                                | 11842.19                      |
| 2010            | 1809                                | 13651.19                      |
| 2011            | 2480                                | 16131.19                      |
| 2012            | 2202                                | 18333.19                      |
| 2013            | 2432.7                              | 20765.89                      |
| 2014            | 2602                                | 23367.89                      |
| 2015            | 2619.5                              | 25987.39                      |
| 2017            | 2618                                | 28605.39                      |
| 2018            | 2608                                | 31213.39                      |

3.2. Gas Drainage Analysis
(1) The amount of gas emission from the heading face is reduced. Before gas pre-drainage, a coal roadway driving face with a cross-section of 10.4-12.7 m², when the single heading is more than 100 m a month, the gas emission from the working face is as high as 10 m³/min, and the average gas emission from 100 m roadway is 5.02 m³/min. It takes four 28 Kw local fans to supply air simultaneously to reduce the gas concentration of the return air flow to less than 1%. After pre-drainage of gas, the gas emission from the same section of coal roadway driving face is significantly reduced. The average gas emission from 100-meter coal roadway is only 1.78 m³/min, as shown in Table 2.
Table 2. Contrast Table of Gas Emission in Driving Face before and after Drainage

| Category                  | Name of working face          | Driving length (m) | Gas emission (m³/min) |
|---------------------------|-------------------------------|--------------------|-----------------------|
| No extraction before excavation | 102 transport chute           | 110                | 8.58                  |
|                           | 101 transport chute           | 88                 | 6.6                   |
|                           | 104 transport chute (East)    | 84                 | 2.59                  |
|                           | 104 transport chute (West)    | 74                 | 2.84                  |
|                           | 104 return air chute (East)   | 154                | 2.9                   |
|                           | 104 return air chute (West)   | 76                 | 4.4                   |
|                           | 109 roof lane                 | 56                 | 4.89                  |
|                           | East 102-1 tunnel resolution  | 73                 | 3.08                  |
|                           | 103 transport chute           | 120                | 1.7                   |
|                           | 103 return air chute          | 117                | 3.15                  |
|                           | 106 return air chute          | 167                | 0.9                   |
|                           | 106 transport chute           | 138                | 1.45                  |
|                           | 110 return air chute          | 100                | 1.71                  |
|                           | 110 floor roadway             | 102                | 3.6                   |
|                           | 109 return air chute          | 76                 | 2.23                  |
|                           | 1112 transport chute          | 112                | 1.87                  |

(2) The gas emission from the mining face is reduced. After gas extraction, the gas emission from the mining face has been greatly reduced. 102-1 working face in West-1 mining area has been exploited since April 1990. With the advancing of the working face, the gas emission increased from 5.5 m³/min in April to 10.56 m³/min in September, and the number of gas exceeding the limit in the upper corner reached 51 times. After gas extraction, the gas emission and the number of gas exceeding the limit in the upper corner of 102-1 working face are obviously reduced.

(3) The risk of coal seam outburst is reduced. The outburst risk of working face is predicted by the initial velocity of gas emission from boreholes and the amount of drilling cuttings. The number of times exceeding the standard in the non-extraction area is much higher than that in the extracted area. Percentage 70 of the exceeding the standard of prediction index occurred before gas pre-drainage in 40 times. After gas extraction, the phenomenon of exceeding the standard of prediction index was greatly reduced in the course of coal roadway driving. Only a few roadways had exceeded the critical value of outburst index, accompanied by dynamic effects such as coal gun sound.

4. Analysis of Gas Emission Characteristics

(1) There is a large amount of gas emission in the distribution area of tectonic coal. According to the influence of faults and folds on gas occurrence, it is predicted that in the structural influence zone of F12 fault group on the southern wing of the minefield, the absolute gas emission from the first coal seam is 25-40 m³/min, near the area of 100-150 m on the upper and lower walls of F3, F18 and F16 faults, and the absolute gas emission from NO.1 coal seam is 25-30 m³/min; and the NO.3 coal seam is close to the F3 fault. The absolute gas emission is 10-25 m³/min in the area of 100-150 m in the upper and lower panels.

(2) There is a large amount of gas emission in the methane distribution area. According to the influence of natural gas composition on gas occurrence in coalfield coal seam, the content of CH4 of NO.1 coal seam is relatively high, and the absolute gas emission amount reaches 25 m³/min; the absolute gas emission amount in N2-CH4 distribution area ranges from 10 to 25 m³/min; and in N2-CO2-CH4 distribution area, the content of CH4 is higher than that in N2-CH4 distribution area. The absolute gas emission is between 5 and 10 m³/min with low content. In the N2 distribution area, CH4 content is the lowest, and the absolute gas emission is 5 m³/min.

In the area of CH4 distribution, the content of CH4 in NO.3 coal seam is relatively high, and the absolute gas emission amounts to 10 m³/min-25 m³/min, and 5-10 m³/min in the area of N2-CH4 distribution.
(3) Gas emission is large in areas with extra-thick coal seam and complex coal seam structure. According to the influence of coal seam thickness and structure on gas occurrence, the absolute gas emission is 10 m$^3$/min in an area with coal seam thickness less than 10 m, and 10 m$^3$/min to 25 m$^3$/min in an area with coal seam thickness greater than 10 m.

The absolute gas emission is 5 m$^3$/min in the area with thickness less than 5 m, and 5 m$^3$/min in the area with thickness greater than 5 m. The absolute gas emission is 5 m$^3$/min-15 m$^3$/min. The gas content of NO.3 coal seams is high in the coal seam thickening area in the western part of the mine field. It is estimated that the absolute gas emission is 15-25 m$^3$/min.

(4) Gas emission in other areas increases gradually with the depth of coal seam. The roof lithology of No. 1 and NO.3 coal seam is argillaceous siltstone or fine siltstone without structural influence. The gas emission in areas with stable coal seam thickness and simple structure is 5-25 m$^3$/min and 5-15 m$^3$/min.

5. Analysis of Gas Emission from Coal Seam

There is no outcrop in Weijiadi Coal Mine. The vertical distance between the coal seam and the surface is 350 m to 900 m. The coal seam in the south wing of the minefield is shallow, and the coal seam in the north wing of the minefield is deeper. The absolute gas emission is 12-55 m$^3$/min and the relative gas emission is 10-164 m$^3$/t. During mine construction and production, gas emission from coal seam is extremely uneven and coal and gas outburst occurs. According to the statistical analysis of the summary table of gas drainage and drainage over the years, there are three characteristics of mine gas emission:

1) There is a large amount of gas emission in the first mining seam of a mine, and coal and gas outburst occurs. Because the gas in the surrounding rock and the lower part of the stratum will be released at the same time during the mining process of the first mining stratum, the amount of gas emission is large.

According to seismic and topographic deformation measurements, the Dabao coalfield in Jingyuan is in a multi-stage, multi-stage and still active tectonic belt. Because of tectonic stress, the physical and mechanical properties of coal are seriously damaged, and the surface area of adsorbed gas is increased. When the stope approaches the tectonic high stress field, the equilibrium state is destroyed. The high stress of state means the dynamic phenomena of coal and gas outburst.

2) The content of free gas in coal seam is on the high side, resulting in a great difference between gas content and emission. Gas in coal seam is mainly adsorbed gas. When the external conditions are constant, the adsorbed gas and free gas in coal body are in equilibrium. When the external conditions (such as gas pressure, etc.) change or impact the coal body, the equilibrium state of adsorbed gas and free gas in coal seam is destroyed. Free gas is the first one. Release, then absorb gas quickly to supplement, but the content of free gas in Weijiadi mine coal seam is too large, which results in a large difference between gas content and emission in some areas, such as 102 working face near the structural influence zone of F$^{1,2}$ fault group, gas content in coal seam is 3-4 m$^3$/t, but gas emission in this area is large. Quite high, the main coal seam gas geological characteristics table, as shown in Table 3.

| Name of Coal Seam | Thickness (m) | Ash content (%) | Volatile Compounds (%) | Gas content(m$^3$/t) |
|-------------------|---------------|-----------------|------------------------|---------------------|
| NO.1 coal seam    | 0.23~37.78    | 7.61~33.11      | 24.81~34.08            | 0.13~10.39         |
|                   | 13.08         | 17.22           | 29.36                  |                     |
| NO.2 coal seam    | 0.28~14.37    | 15.53~34.91     | 24.28~32.8             | 0.12~4.79          |
|                   | 3.84          | 24.45           | 29.9                   |                     |
| NO.3 coal seam    | 0.29~15.03    | 15.53~34.91     | 24.28~32.8             |                     |
|                   | 5.53          | 24.45           | 29.9                   |                     |

(3) The amount of gas emission increases linearly with the increase of the length of roadway driving. Gas emission from coal seam roadway increases with the increase of driving length. According to the mathematical statistics analysis of the relationship between the gas emission (m$^3$/min) and the length (m) of the coal roadway driving face, such as 104 conveyance road (east, west), 101 return air tunnel,
103 return air tunnel, East 102-1 relief tunnel, 2301 relief tunnel and so on, it is found that the two have obvious positive proportional linear changes, as shown in Table 4.

Table 4. Mathematical simulation expression of length and gas emission of driving roadway

| Name of roadway               | Mathematical expression       | Correlation coefficient | Maximum Statistical Scope                  |
|------------------------------|-------------------------------|-------------------------|--------------------------------------------|
| 104 transport chute (East)   | \( Q = 1.7025 + 0.0077L \)   | 0.922                   | Driving length/L                           |
| 103 return air chute         | \( Q = 0.039 + 0.0021L \)    | 0.914                   | Gas emission/Q                             |
| 101 return air chute         | \( Q = 5.23 + 0.012L \)      | 0.841                   |                                            |
| 104 transport chute (West)   | \( Q = 1.64 + 0.0104L \)     | 0.921                   |                                            |
| East102-1 relief tunnel      | \( Q = 0.3956 + 0.0059L \)   | 0.92                    |                                            |
| 2301-2 relief tunnel         | \( Q = 0.018 + 0.0024L \)    | 0.86                    |                                            |

6. Conclusion

(1) The main coal seams in Weijiadi Coal Mine are NO.1 and NO.3 coal seams, and the gas emission from coal seams increases with the increase of the burial depth of coal seams.

(2) Through the implementation of gas extraction measures in Weijiadi Coal Mine, the risk of coal seam outburst has been greatly reduced, and the number of gas exceeding the limit has been greatly reduced.

(3) Absolute gas emission is 10 m³/min in areas with NO.1 coal seam thickness less than 10 m, 10 m³/min to 25 m³/min in areas with more than 10 m coal seam thickness, 5 m³/min in areas with NO.3 coal seam thickness less than 5 m, 5 m³/min in areas with more than 5 m coal seam thickness and 5 m³/min to 15 m³/min in areas with absolute gas emission.

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References

[1] Xu Qingwei, Wang Zhaofeng. The error existing in the predictions of gas emission quantity using mine statistical method and its correction [J]. China Coal, 2015, 10(2): 118-120.

[2] LIU Yang, ZHANG Shuhai. Influence of Limestone on Gas Emission Prediction in Yangquan Mining Area[J]. Journal of Test and Measurement Technology, 2017, 31(2): 170-174.

[3] ZHANG Wendong, HU Yu. Prediction of Gas Emission in Coal Mine Based on Improved PCV and SVM [J]. Journal of North University of China(Natural Science Edition), 2018, 39(3): 303-309.

[4] XIAO Dan. Discussion on the Methods of Gas Emission Prediction[J]. Industrial Safety and Environmental Protection, 2014, 40(3): 61-65.

[5] HE Qing. Present Research Situation on Gas Emission Prediction of Working Face and Its Developing Trend[J]. Mining Safety & Environmental Protection, 2016, 43(4): 98-101.