Analysis the Influence Factors and Deviation of Gas Outflow in Resumed Mine

Wang Dong, Ding Hong
Chongqing Research Institute Co, Ltd. China Coal Technology and Engineering Group, Chongqing 400037, China

Corresponding author’s e-mail address: 381300902@qq.com.

Abstract: In view of the problem of insufficient wind distribution basis during recovery, on the basis of analyzing the influence factors of gas outflow in the resumed mine, the research object is taken by the Limin coal mine in Hunan Province, and the gas excitant quantity prediction and deviation analysis are carried out in different production periods when the mine is produced by the source and statistics method. The results show that the mine relative gas outflow prediction error is 6.98 to 19.96 percent, controlled by coal seam thickness and gas content, mining depth geological conditions and other natural factors, while the mine absolute gas outflow prediction error is 20.89 to 44.01 percent, controlled by mining technology factors such as mining scale, recovery schedule and shutdown time.

1. Introduction
Mine gas outflow forecast can quantitatively judge the gas outflow at different mining sites, provide a calculation basis for the wind distribution of mine roadways, and ensure the ventilation safety during the extraction period [1-2]. Therefore, whether the forecast of mine gas outflow is accurate will directly affect the prevention and control of coal mine gas disaster and the protection of mine mining activities [3].

In view of the method of predicting gas outflow in the mine, scholars at home and abroad have carried out a large number of related research, Chen Yang[4] and others have studied the development and practice of gas out pouring source prediction method, Zhao Pengwei[5] has used mine statistics to predict the gas out pouring volume of the comprehensive surface, Dai Guanglong [6] and others predicted the gas outflow of the protective layer mining work surface. Zhang Yao [7] analysis the basis of the surface gas outflow prediction and gas source, Fu Hua [8] based on coupling algorithm to establish a coal mine gas surge forecast model, Xiao Dan [9] improved the reliability of gas surge prediction results. The above scholars mainly practiced the gas outflow forecast method in the new construction and production mine, but had little research on the prediction of gas excitant gas outflow in the recovered mine after the shutdown.

Based on this, on the basis of analyzing the influence factors of gas outflow forecast in the resumed mine, the method and principle of the gas outflow forecasting method of different mines are studied, and the gas outflow in different production periods is predicted by the source and statistical methods of the mine in accordance with the method of mining exploration and the conditions of extraction replacement, coal seam and gas deposit. The prediction deviation is analyzed to provide a reliable calculation basis for the roadway wind distribution in the resumed mine.
2. Gas outflow prediction methods and analysis of influencing factors

2.1 Source method
The process of predicting gas outflow in the mine using the sub-source method is shown in Figure 1, which is mainly based on the amount of gas outpouring source from different mining sites in the mine and the size of the gas outflow volume, and the volume of gas outflow from the production extraction area and the various production periods of the mine is obtained by quantitative prediction of the source relationship[10-11].

![Figure 1. mine gas outflow calculation process](image)

The use of the source method to predict the gas outflow of mine is mainly influenced by the natural factors and production factors of the mine.

2.1.1 Natural factors. The natural factors of the mine mainly include the thickness of the coal seam, the spacing of the coal seam and the content of the original gas. The study shows that when the size of the mine is larger, the greater of absolute gas outflow for the increase in the daily output; When the coal seams are used in different mining order, the gas outflow of mining layer and adjacent layer is quite different; When the mine uses different recovery methods, the lower the recovery rate of the return surface, the greater the amount of gas gushing on the back-picking surface. When the mine uses different recovery methods, the greater the amount of gas gushing on the return work surface.[12]

2.1.2 Production factors. Mine production factors mainly include mining scale, mining order and recovery method. The study shows that when the larger the mining scale, the increase in the daily output of the mine leads to the greater the absolute gas outflow, when the coal seams are used in different mining sequences, the gas outflow of the mining layer and the adjacent layer is larger, and when the mine uses different recovery methods, the lower the recovery surface recovery rate, the greater the gas gushing volume of the recovery work surface[13].

2.2 Statistical method
The statistical method is based on the gas outflow in the existing production area of the mine, and the statistical analysis method is used to obtain the law of the change of the gas outflow of mine with the depth of exploitation, and when the production factors and natural factors in the forecast area are similar to the production area, the gas outflow in the forecast area of the mine is calculated quantitatively[14-15].

But for the resumption of production mines, the amount of coal gas out pouring is not only affected by natural factors such as coal seam deposit, gas deposit and production factors such as mining scale, mining order, recovery process, etc., but also affected by the change of time factors caused by discontinuation.

In view of this, for the impact of the shutdown time, according to the pre-stop production of mine gas outflow, the use of statistical analysis methods, to obtain the mine gas out flow with the production time of the law, and then predict the recovery of the mine gas gushing volume.

The amount of gas pouring in the mine is related to the mining year as follows:
$$q = q_0 + \frac{T - T_0}{a} \quad (1)$$

In the formula, $q$ is absolute (or relative) gas outflow swell under mining year, $m^3/min$ (or $m^3/t$); $q_0$ is absolute (or relative) gas outflow swell at $T_0$ (year) when the mine is shut down, $m^3/min$ (or $m^3/t$); $a$ is absolute (or relative) gas outflow gradient, year-$\cdot$min/$m^3$ (or $\cdot$t/$m^3$).

3. Application

3.1 Mine Profile

Limin Coal Mine in Hunan Province was discontinued in 2001 due to policy reasons, and resumed production in 2009, with a design production capacity of 300kt/a, and a design service life of 21.5a. The mine contains 3 layers of coal-mining seam, of which the main mining is 3# coal, the characteristics of the minable seam can be seen in Table 1.

3.2 Forecast parameters

The statistical results of the raw gas content of 3# coals with high mining standards are shown in Table 2, and the statistical results of coal gas outflow in the past years are shown in Table 3.

3.3 Source method prediction results and analysis

The calculation formula for the gas gushing volume of the back-picking face is as follows:
In the formula, \( k_1, k_2, k_3 \) is surrounding rock, coal-throwing and preparation of roadway gas outflow coefficients, respectively 1.2, 1.05 and 0.83; \( h, h_0, H \) is mining layer, adjacent seam coal thickness and high, m; \( W, W_0, W_0 \) is raw and residual gas content of mining layer, adjacent layer, m\(^3\)/t; \( k_i \) is near-layer gas emission factor, 1# coal is 0.92, 5# coal is 0.50.

The calculation formula for the amount of gas gushing out of the excavation face is as follows:

\[
q_v = q_{oa} + q_{we} \\
q_{oa} = D \times v \times V_0 \left( \frac{2}{V_0} - 1 \right) \\
V_0 = 0.026 \times W \times \left[ 4 \times 10^4 \times V_{daf}^2 + 0.16 \right] \\
q_{we} = S \times v \times \gamma \times (W - W_0)
\]

In the formula, \( D \) is coal wall circumecarnicity, m; \( v \) is excavation speed, take 100m/month; \( L \) is excavation length, take 800m; \( V_0 \) is coal wall gas gushing out of the initial speed, m\(^3\)/m\(^2\)-min; \( V_{daf} \) is volatility, take 7.89 percent; \( S \) is lane break area, take 6.8m\(^2\); \( \gamma \) is view density, take 1.36t/m\(^3\).

The calculation formula for gas outflow in the production mining area is as follows:

\[
q_m = \frac{K \left( \sum_{j=1}^{n} q_{si} \times C_i + 1440 \sum_{j=1}^{n} q_{si} \right)}{C_0}
\]

In the formula, \( K \) is mining area gas out pouring coefficient, take 1.25; \( C_i \) is back harvesting surface daily output, one mining area to take 382 t/d, two mining area to take 491 t/d; \( C_0 \) is Mining area daily output, one mining area to take 420 t/d, the two mining area to take 540 t/d.

The calculation formula for the amount of gas from the mine is as follows:

\[
q_r = \frac{K' \sum_{i=1}^{m} q_{si} \cdot C_i}{\sum_{i=1}^{m} C_i}
\]

In the formula, \( K' \) is gas outflow factor in the mined area of the mined area, take 1.25. The production of Limin coal mine is divided into four periods: the first period (one mining area, 50m mark and two mining area, 150m mark), the second period (one mining area -140m elevation and two mining area s150m mark), the third period (one mining area and the height of the 50m elevation and second mining area -140m elevation) and the fourth period (one mining area -140m elevation and two mining area -140m elevation), the forecast results of the mine gas outflow in different periods are shown in Figure 2.

![Figure 2. prediction results of source method](image-url)
As can be seen from Figure 2, the distribution method is used to predict that the mine's relative gas outflow range is 55.34 to 90.59 m$^3$/t when the mine is produced, and the absolute gas outflow range of the mine is 36.90 to 60.39 m$^3$/min. Influenced by the natural and production factors of the mine, the gas outflow of the mine gradually increased from the first period to the fourth period.

3.4 Statistical prediction results and analysis

According to the situation of coal gas outflow in Limin coal mine over the years, using statistical analysis method, fitting the absolute gas outflow of the mine and the relationship between the coal mine relative gas outflow and the mining year. The coal gas outflow in 12 mining years has increased with time to an increasing trend, the mine absolute gas outwelling ($q_{jd}$) and the mine relative gas outwell ($q_{xd}$) and mining year (n) fit relationship is:

$$\begin{align*}
q_{jd} &= 0.77n + 13.79 \\
q_{xd} &= 2.17n + 16.09
\end{align*}$$  \hspace{1cm} (6)

Limin coal mine stopped production in 2001, 1999-2001 mine gas gushing data is missing, according to the above fitting relationship can be obtained from the relationship between limin coal mine in 2001 absolute gas gushing volume of 25.34 m$^3$/min, the mine relative gas gushing volume of 48.64 m$^3$/t.

At the same time, Limin coal mine resumed production in 2009, assuming that the mine after the resumption of production and the pre-production of the mine gas outflow is consistent. Due to the service life of 9.6 years in the first mining area and 15.2a in the second mining area, assuming that the first mining surface started to recover in 2011, the annual years at the time of the mine production were the first period (2013-2014), the second period (2015-2016), the third period (2017-2018) and the fourth period (2017-2010). According to the relationship between mine gas outflow and mining year (n), the absolute gas outflow of the mine and the relative gas outflow of the mine in the four periods of production can be obtained as shown in Figure 3.

![Figure 3. prediction results of statistical method](image)

As can be seen from Figure 3, the statistical method is used to predict that the relative gas gushing range of the mine when limin coal mine is produced is 59.49 to 72.51 m$^3$/t, and the absolute gas outflow range of the mine is 29.19 to 33.81 m$^3$/min. Influenced by the natural factors, production factors and time factors of the mine, the gas outflow of the mine also increased gradually from the first period to the fourth period.

4. Comparison of forecast results and deviation analysis

The prediction results of coal gas outflow in different periods using statistical and forecasting methods at different times of Limin coal mine production are shown in Figure 4.
As can be seen from Figure 4, the law of change of relative gas outflow in mines predicted by statistical and source methods is basically the same, the prediction error is 6.98 to 19.96 percent, the prediction error increases gradually with the advance of the production period, and the absolute gas outflow of mine predicted by statistical method is much smaller than the source method, and the prediction error is 20.89 to 44.01 percent, the prediction error also increases with the progress of the production period.

The relative gas outflow of the mine is mainly controlled by natural factors such as coal thickness of mining and adjacent layers, the original gas content of the coal seam, and the geological conditions of the depth of exploitation. And the mine absolute gas outflow is mainly controlled by the mining scale, mining order, recovery progress, and other time factors. When using statistical methods to predict the absolute gas outpouring of the mine, it thinks that the absolute gas out pouring volume of the mine after the resumption and production before the production of little change, it’s not much change for the absolute gas outflow between the resumption and shutdown. And with the change of mining period, the gas outflow of mine is increasing linearly, but when the source method is used to predict, the absolute gas outflow of mine is increasing gradually because of the irregular change of mine production output, resulting in the prediction deviation is larger than the coal mine relative gas outflow.

5. Conclusion
The error of relative gas outflow of mine by statistical and source method is 6.98 to 19.96 percent, mainly controlled by natural factors such as coal thickness of mining and adjacent layers, raw gas content of coal seams, geological conditions of depth of mining, and the error of absolute gas outflow of mine reaches 20.89 to 44.01 percent, mainly controlled by the scale of mining, mining order, recovery schedule and other production factors resulting in the time change of production factors.

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