Optimization of Gas Drilling in Pre-pumping Coal Seam of Gas Tunnel

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Abstract. In order to optimize the gas drilling in pre-pumping coal seam and strengthen the gas emission effect, this paper uses Chenggui high-speed railway Baiyanglin tunnel as the research object. The FLUENT numerical simulation software is used to simulate the change of coal seam gas pressure during the process of gas emission and the influencing factors of the effect of gas emission. According to the numerical simulation results, the parameters including hole spacing, hole depth and aperture are optimized. The results show that the recommended diameter of the pre-emission gas is 75 ~ 100mm, the drilling depth is 1.5 ~ 2.5m, and the hole spacing is 2m.

1. Introduction

Coal and gas eruption accidents often occur when the tunnel passes through the coal seam bearing area. Coal and gas eruption is due to the destruction of the dynamic balance between the two, a large amount of gas with the sudden emission of coal, is an extremely complex dynamic phenomenon, it is sudden, not completely knowable, it is difficult to prevent it completely. Therefore, before crossing the coal seam, some safety measures should be taken to reduce the gas pressure in the coal seam. The purpose of prevention and control of eruption is to change the basic conditions of eruption, to make it not happen or reduce the intensity of eruption, and to take necessary safety protection measures.

The purpose of studying the law of gas migration in coal body is to provide theoretical basis for the design of three elements of emission borehole: hole diameter, hole depth and hole spacing, and to provide theoretical basis for these three elements. These three elements basically determine the quantity of gas extraction borehole engineering, to ensure that the extraction standards and save the important role of extraction funds is obvious. Therefore, it is found that there are two main methods for obtaining the spacing of gas pre-emission boreholes, i.e., the actual measurement method and the theoretical calculation method[1-3]. In the study of borehole depth, a few scholars have noticed that the negative pressure decreases rapidly with the increase of borehole depth, so they should avoid the influence of negative pressure drop in the design of pumping and draining[4]. In comprehensive research, most researchers can pay attention to the influence of hole spacing and pumping time on pumping up to standard[5], and a few scholars have studied the influence of hole depth and pumping time on pumping up to standard.

2. On-site gas emission scheme

Xingaopo Tunnel is 3960m long, located in the north of Yunnan-Guizhou Plateau, the Yangtze paraplatform, the eastern Yunnan platform fold. The geological structure is complex. According to the drilling results, there are three sections about 2800m across coal measure strata, accounting for 35% of the total length. D3K301+400 ~ DK303+000 is low gas, DK303+000 ~ DK305+900 is high gas.
According to geological exploration, Xingaopo Tunnel crosses coal seam twice, and the mileage is about DK303+175 ~ DK303+215, DK303+760 ~ DK303+805 respectively. According to the analysis of coal exploration, borehole and dip angle hole in tunnel, the angle between coal seam and tunnel is about 45°.

The minimum distance from the outer edge of the control range to the outline of the roadway (including the outline of the roadway in the expected front coal-uncovering section) shall not be less than 5m when determining the area eruption control range. Referring to the construction experience, the gas emission scheme is considered according to the emission radius of 1.5 m, the distance between the final bores is 2m, and the coal seam control range is 45m, as shown in Figure 1.

3. Establishment of gas emission model

In order to study the flow law of coal seam gas under the action of gas emission, according to the factors influencing the gas emission effect, combined with the construction situation on the spot, the study conditions are set as follows: (1) To study the influence of borehole diameter on gas emission effect, and set the borehole diameter as 60mm, 75mm and 100mm; (2) The influence of borehole depth on gas emission effect is studied, and the borehole depth is set at 0.5 m, 1.5 m, 2.5 m; (3) The effect of different hole-bottom spacing on gas emission was studied. The hole-bottom spacing was set at 1m, 2m, 3m, 4m.

According to the above assumptions and research conditions, the angle between coal seam and tunnel is set to 45°, the thickness of coal seam is 4m, the coal seam intersecting with tunnel is taken as the gas control area, and the model is established as shown in Figure 2.

4. Analysis of research results

4.1. Effect of drilling diameter on gas emission

The working conditions for obtaining the pore diameter are R=0. 03m, R=0. 0375m and R=0. 05m. The gas pressure in the coal seam is as shown in Figure 3.
Comparing the gas pressure of coal seam under different borehole diameters, we can see that the gas pressure has a similar change rule, and the gas pressure decreases with the increase of borehole diameter. As can be seen from FIG. 3, the gas pressure near the 100 mm borehole is 467215 Pa, and the gas pressure near the 60 mm borehole is 526642 Pa, reducing by 11.3%. The gas pressure is 1061770Pa at the edge of 100mm coal seam and 1062210Pa at the same position of 60mm borehole, which decreases by 0.17%. Therefore, the diameter of the borehole has a greater impact on the vicinity of the borehole, and the farther away from the borehole, the smaller the impact.

The change of gas flow rate under different borehole diameters is shown in Figure 4.

The change rule of gas flow rate is the same under different borehole diameters. With the increase of emission time, the gas flow rate gradually decreases and finally tends to be stable. The larger the aperture, the higher the gas flow rate in the same emission time. When the emission time is 30 days, the gas flow rate of the gas emission hole with the diameter of 100 mm is $2.91 \times 10^{-3}$ m$^3$/min, which is 6.5% higher than that of the gas emission hole with the diameter of 60 mm. Therefore, the larger the diameter of the borehole, the greater the gas flow, the higher the total amount of gas emission.

With the increase of gas flow rate, the total amount of gas pumped and discharged increases. Properly increasing the diameter of the borehole is beneficial to the effect of gas emission. Combining with the field construction equipment, it is suggested that the diameter of borehole should be 75 ~ 100mm.

4.2. Influence of drilling depth on gas emission effect

The parameters of coal seam tend to be stable when the single hole pumping time is about 120 days. Therefore, this working condition is taken as the limit working condition of single hole gas emission, and the variation rule of relevant parameters under different coal feeding depths is compared. According to the maximum thickness of coal seam on site, the working conditions of borehole coal feeding depth are set as 0.5 m, 1.5 m, 2.5 m and 3.5 m. When the gas pressure in the coal seam tends to be stable, the gas pressure cloud chart is shown in Figure 5.
With the increase of coal depth, the contact surface of coal body subjected to pumping and discharging action is gradually increased, and the pumping and discharging effect is enhanced, and the influence range of pumping and discharging is gradually extended to the edge of coal seam. When the coal depth is 2.5 m, the pumping and discharging effect is weakened, and the gas pressure cloud picture area is uniform and consistent. When the coal depth is 1.5 m, the participating gas pressure at the upper edge of the tile coal seam thickness direction is between 0.41 and 0.53 MPa, and the effective gas emission range has penetrated through the coal seam. According to the coal seam thickness at the site and considering the influence of construction factors, the coal feeding depth should be between 1.5 and 2.5 m.

The change rule of gas flow rate is the same under different coal depth conditions. The gas flow rate decreases with the increase of emission time and finally tends to be stable. The greater the coal depth, the greater the gas flow in the same emission time. When the emission time is 30 days, the gas flow rate of the gas emission hole with 3.5 m coal depth is $8.66 \times 10^{-3} \text{ m}^3/\text{min}$, which is 123.2% higher than that of the hole with 0.5 m coal depth. Therefore, with the increase of coal depth, the emission flow rate of gas borehole can be obviously increased. With the increase of gas flow rate, the total amount of gas pumped and discharged increases. Therefore, the appropriate increase of coal depth is beneficial to the gas emission effect. Combining with the difficulty of field construction, it is suggested that the coal feeding depth should be 1.5 ~ 2.5 m.

4.3. Influence of hole-bottom spacing on gas emission effect

When the hole bottom spacing is set as D=1m, D=2m, D=3m, D=4m, and the emission time is 120d, the gas pressure cloud chart of each layer is shown in Figure 7.

When the emission time is 120d, the influence radius reaches 11m, the pressure distribution is elliptical and radial, and the hole spacing has little influence on the residual gas pressure distribution in stable coal seam. Because of the emission effect of two holes, the gas pressure near the borehole is small. With the increase of the distance between the boreholes, the gas pressure between the boreholes tends to increase.

Taking 30% emission rate as the eruption elimination index to prevent gas eruption, that the gas pressure gradually decreases and the effective emission radius gradually increases with the increase of
time, and after the emission time reaches 90 days, the growth rate of the effective radius decreases and the effective radius tends to be stable. The borehole distance has obvious influence on the effective radius of gas emission, and the larger the borehole distance is, the larger the gas emission radius will be in the same emission time. When the gas pressure in the middle of the borehole reaches higher than the eruption elimination limit, the maximum borehole bottom spacing under this construction period. Taking 30d as an example, when the distance between the borehole bottom and the borehole bottom is more than 4m, the gas pressure in the middle of the borehole is greater than the eruption elimination limit. Therefore, when the gas emission period is 30 days, the effective emission radius is 2 m, and the hole bottom spacing shall not be greater than 4 m. The gas flow rate between different hole distances is shown in Figure 8.

![Figure 8. Gas flow at different pore bottom spacing conditions](image)

As can be seen from FIG. 8, the gas flow rate of the borehole is the same under different hole bottom spacing conditions. With the increase of time, the gas flow rate gradually decreases, the emission time reaches about 120 days, and the gas flow rate tends to be stable. The larger the hole bottom spacing is, the larger the gas flow is in the same emission time. When the emission time is 30 days, the gas flow rate of the gas emission hole with the hole bottom spacing of 4 m is $5.29 \times 10^{-3} \text{ m}^3/\text{min}$, which is 14.8% higher than that with the hole bottom spacing of 1 m. When the hole bottom spacing is 4m, the effective emission radius is 2m, and the emission time is 150d, the eruption elimination standard can not be reached, so it is necessary to prolong the construction period or to densify the drilling hole to eliminate eruption. Therefore, it is suggested that the effective radius of the new high slope tunnel in coal seam should be 1 m and the distance between the bottom and the hole should be 2 m.

5. Conclusion
1) The larger the diameter of the borehole is, the larger the effective radius of the borehole is, the wider the influence range of the gas emission effect is, and the better the gas emission effect is. Therefore, the proper increase of the diameter of the borehole is beneficial to the gas emission effect. Combining with the field construction equipment, it is suggested that the diameter of the borehole should be 75 ~ 100mm.

2) The bigger the borehole depth is, the wider the influence range of gas emission is; the bigger the effective radius is, the stronger the gas emission effect is; the bigger the gas flow is, the more the total amount of gas emission is. Therefore, properly increasing the coal depth is beneficial to the effect of gas emission. It is suggested that the borehole depth should be 1.5 ~ 2.5m.

3) With the increase of the distance between boreholes, the interaction between boreholes is weakened. Based on the 30% emission rate, the relationship between the emission period and the distance between boreholes and boreholes is obtained. The smaller the distance between boreholes and boreholes is, the shorter the gas emission period is. It is suggested that the distance between boreholes and boreholes should be 2m and the emission period should be 70d.

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