Experimental Study on Gas Extraction Effect of Conventional Drilling in Coal Mining Face

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Abstract. In order to study the effect of conventional drilling gas extraction technology, combined with the observation results of upward drilling and downlink drilling field test in 81309 working face of Baode Mine. The analysis of field test data shows that under the same gas control effect, the average gas concentration and gas purity of uplink drilling are higher than that of downlink boreholes. In the extraction range, the average pumping concentration of uplink boreholes is 1.134 times higher than that of downlink boreholes, while the average pure gas flow rate of uplink boreholes is 1.296 times higher than that of downlink boreholes. The test results show that the uplink conventional drill Hole has better pumping concentration stability and extraction effect than downlink conventional drilling.

1. Introduction
In recent years, China has made breakthrough progress in the management of coal mine safety production, but coal mine safety accidents have occurred from time to time. Among all coal mine accidents, gas accidents account for the largest proportion, accounting for more than 30% of all accidents, so the prevention of gas disasters is the top priority of coal mine safety production [1-3]. The conventional drilling layout of this coal seam in high gas mine is different, and the gas drainage effect achieved is different [4-6]. The author analyzes the two types of conventional borehole groups on the working face and down of Baode Coal Mine 81309, and compares the drainage effect in order to provide guidance for the further popularization and application of the drainage technology.

2. Principles of drilling gas drainage technology
After the coal mining work is advanced forward, the original stress balance state around the goaf is destroyed, causing the transfer and redistribution of the surrounding rock stress, which in turn causes the deformation, movement and destruction of different rock layers from the bottom to the top under the new stress [7-8]. According to the "key layer theory of rock formation control" proposed by Academician Qian Minggao [9], the overburden strata along the advancing direction of the working face can be divided into the coal wall support influence zone, the separation zone, and the re-compaction
zone, namely the “three horizontal zones”. It can be divided into three zones: caving zone, roof fissure zone and surface bending subsidence zone in the vertical direction.

Mining fissures are mainly divided into two categories: one is the lateral separation fissures, that is, the interlayer fissures that appear between layers after the rock layer sinks. It acts as a gas gushing channel, causing the coal seam to swell and deform and relieve the gas pressure. The other type is the vertical fracture fracture, which is the through-layer fracture formed as the rock layer sinks and breaks, and it forms the channel of gas and water between the upper and lower rock layers [10]. Under the influence of re-mining, both types of fissures have developed in a large amount, which greatly improves the permeability of the coal seam and adjacent coal seams, and the coal rock layer has the effect of decompression and permeability enhancement.

3. Geological survey of Baode Coal Mine

The Baode Coal Mine is located on the eastern edge of the Ordos Basin, the western wing of the northern section of the Luliang Uplift, and the northern part of the Hedong Coalfield. The structure in the minefield is simple, with a gentle monoclinic structure, and wide and gentle undulations. The stratigraphic occurrence is generally 350° in strike, 260° inclination, 3-9° inclination, and generally about 5°. No large faults and collapsed columns were found. The main coal-bearing strata in the minefield are the Lower Permian Shanxi Formation and the Upper Carboniferous Taiyuan Formation. The Shanxi Formation has an average thickness of 53.13m and mainly contains 3 coal seams, namely the 4th, 6th and 8th coal seams. The 8th coal seam is a stable mineable coal seam and the 4th and 6th coal seams are non-mineable coal seams. The average total thickness of the coal seam is 8.84m, and the coal content coefficient is 16.64%; the average thickness of the minable coal is 7.55m, and the minable coal seam coefficient is 14.21%.

The absolute gas emission of the mine is 106.62 m³/min, the relative gas emission is 13.16 m³/T, the maximum absolute gas emission of the mining face is 15.78 m³/min, and the maximum absolute gas emission of the driving face is 5.67 m³/min, which is a high gas mine. Coal dust in No.8 coal seam is explosive. The spontaneous combustion tendency grade is class II, belonging to spontaneous combustion coal seam.

4. Experimental study on extraction characteristics of upward and downward conventional boreholes

4.1. 81309 General situation of Geology and gas in working face

The 81309 working face is adjacent to the 81308 working face to the east, the undeveloped solid coal is to the west, the three-panel centralized auxiliary transportation auxiliary lane is to the north, and the third-panel boundary is to the south. The designed minable length of the working face is 2585m, the inclined length of the working face is 240m, and the coal reserves are 7.37 million tons. The seam floor contour of this working face is 610~648m. The coal seam is generally in the north-south direction, and it is a wide and gentle monoclinic structure inclined to the west. The maximum relative height difference is 30m, the inclination angle is 3–5°, and the average is about 4°.

The working face is mined along the direction of the coal seam. The thickness of the coal seam tends to be thick in the middle and thin on the sides. The thickness of the coal seam at the opening end of the roadway is 7.0m, the thickest in the middle is 8.2m, and the thinnest in the south of the excavation roadway is 5.6m. The coal seam structure is more complicated with gangue 3-4. The maximum thickness of single-layer gangue is 0.6m. The gas content and buried depth of No.8 coal seam follow the linear regression relationship W= 0.0068·H+2.8347, combined with the measured data of the mine safety laboratory, it is predicted that the original gas content per ton of coal in the 81309 working face is 5.87m³/t, and the gas reserves are 43.26 million m³.

4.2. 81309 working face drainage design parameters

(1) Drilling volume per ton of coal
According to the “Code for Coal Mine Gas Drainage (AQ1027-2006)”, the requirements for the drilling volume per ton of coal are shown in Table 1. The 81309 Jiaoshun design drill hole length is 102,400 meters, and the 81309 Jiaoshun No. 1 is used during the excavation period. The directional drilling for the main roadway construction is 125,800 meters, and the drilling volume per ton of coal in the 81309 working face is calculated to be 0.03m³/t.

Baode Coal Mine 8# has a coal seam permeability coefficient of 0.17-0.8m²/MPa² • d, which is a coal seam that can be extracted and tends to be more difficult to extract. According to the design plan of the 81309 working face, the designed drilling volume per ton of coal meets the requirements of the “Code for Coal Mine Gas Drainage”.

Table 1. Drilling volume per ton of coal

| Coal seam category     | Thin seam | Medium-thickness coal seam | Thick coal seam |
|------------------------|-----------|-----------------------------|----------------|
| Easy extraction        | 0.05      | 0.03                        | 0.01           |
| Can extraction         | 0.05~0.1  | 0.03~0.05                   | 0.01~0.03      |
| Extraction of harder   | >0.1      | >0.05                       | >0.03          |

(2) Drilling pre-draining rate
According to the gas drainage data of Baode Coal Mine over the years, combined with the relevant parameters of the adjacent 81308 Jiaoshun borehole, the initial 100-meter borehole gas flow rate is 0.002m³/min and the borehole flow rate attenuation coefficient is 0.007. 4.48 million m³. After calculation, the pre-draining rate of the 81309 working face in the limited pre-draining time is 28.6%.

Table 2. Drilling pre-draining rate

| Working face | Gas reserves (10000 m³) | Lane name       | Drilling volume (m) | Gas drainage volume (10,000 m³) | Pre-drawing rate(%) |
|--------------|-------------------------|-----------------|---------------------|-------------------------------|---------------------|
| 81309 Working face | 4326                     | Jiaoyunshuncao | 102400              | 448                           | 28.6                |

4.3. Drilling equipment
ZDY6000L crawler full hydraulic tunnel drilling machine is used for the up and down conventional drilling construction of 81309 working face. It belongs to the type of self-propelled, low speed and large torque, which is suitable for the large diameter drilling with the construction depth of about 600 m with composite bit, or the bottom power machine, which is mainly used for the near horizontal and long distance gas drainage drilling in the underground construction of coal mine. The structure of drilling rig is shown in Figure 1 and the drilling construction flow is shown in Figure 2.

Figure 1. Schematic diagram of drilling rig structure
4.4. Project overview
The plane layout of the boreholes is located at 81309 working face, and the upward and downward boreholes are arranged along the inclination of 81309 working face. The distance between the opening position of the boreholes and the floor is 1.5m. The opening position of the boreholes is perpendicular to the coal wall. The diameter of the boreholes is 113mm, and the length is 200m. The final boreholes are located in 8 coal seams. The length of sealing section of conventional pre pumping drilling is not less than 8m. The exposed part of coal wall is tee, one end is connected with drilling hole, the other end is connected with buried pipe, the other end is installed with Φ 50 ball valve upward, the buried pipe is connected with ball valve on the top and drain pipe on the bottom. The total exposed length of tee and sealing pipe shall not exceed 20cm. The actual drilling layout in the experimental area is shown in Figure 3.

5. Gas drainage effect of upward and downward boreholes
After the construction of the 81309 working face test borehole was completed, it was immediately connected to the drainage system for pre-drainage. After 146 days of data observation, the average gas
concentration and average pure gas flow monitoring results of the up and down boreholes are shown in Table 3, Figure 4 and Figure 5.

**Table 3.** Statistical table of upward and downward pumping data of 81309 working face

| Pumping days | Gas concentration (%) | Pure flow (m³/min) | Pumping days | Gas concentration (%) | Pure flow (m³/min) |
|--------------|------------------------|--------------------|--------------|------------------------|--------------------|
| 7            | 31.0                   | 0.093              | 7            | 34.6                   | 0.152              |
| 14           | 27.9                   | 0.093              | 14           | 29.1                   | 0.154              |
| 21           | 31.1                   | 0.102              | 21           | 31.7                   | 0.134              |
| 28           | 27.0                   | 0.086              | 28           | 34.4                   | 0.157              |
| 35           | 28.8                   | 0.096              | 35           | 32.0                   | 0.122              |
| 42           | 28.8                   | 0.095              | 42           | 34.5                   | 0.115              |
| 49           | 30.7                   | 0.103              | 49           | 34.4                   | 0.119              |
| 56           | 32.8                   | 0.109              | 56           | 36.5                   | 0.117              |
| C63          | 30.7                   | 0.101              | 63           | 35.3                   | 0.132              |
| 70           | 35.7                   | 0.124              | 70           | 34.2                   | 0.125              |
| 77           | 35.1                   | 0.123              | 77           | 35.7                   | 0.125              |
| 84           | 33.7                   | 0.112              | 84           | 36.5                   | 0.119              |
| 91           | 33.2                   | 0.109              | 91           | 33.2                   | 0.115              |
| 98           | 33.3                   | 0.103              | 98           | 36.5                   | 0.118              |
| 105          | 32.7                   | 0.099              | 105          | 34.9                   | 0.117              |
| 112          | 30.8                   | 0.093              | 112          | 34.7                   | 0.118              |
| 119          | 29.2                   | 0.089              | 119          | 40.1                   | 0.137              |
| 126          | 27.6                   | 0.084              | 126          | 37.2                   | 0.13               |
| 133          | 27.9                   | 0.084              | 133          | 37.1                   | 0.131              |
| 140          | 29.4                   | 0.085              | 140          | 37.4                   | 0.134              |

**Figure 4.** Comparison of gas concentration between upward and downward boreholes
Figure 5. Comparison of pure gas flow in the upward and downward boreholes

It can be seen from the measurement data in Table 3 that the average gas concentration and gas scalar value of the upward drilling are higher than those of the downward drilling. On average, within 140 days of drainage, the average gas concentration of the upward boreholes was 35%, while the average gas concentration of the downward boreholes was 30.87%, and the average gas concentration of the upward boreholes was 1.134 times that of the downward boreholes. That is, the gas concentration of the upward drilling has increased by 13.38% on the basis of the downward drilling; the average pure gas flow of the upward drilling is 0.12855 m³/min, and the average pure gas flow of the downward drilling is 0.0992 m³/min, the average pure gas flow of the upward drilling is 1.296 times that of the downward drilling, that is, the scalar gas drainage of the upward drilling increases by 29.84% on the basis of the downward drilling.

From the comparison of the extracted gas concentration in Figure 4, it can be seen that after 67 days of extraction, the gas extraction concentration of the downward boreholes showed a downward trend, while the gas extraction concentration of the upward boreholes remained above 34%. After 140 days of drainage, the average gas concentration was 37.4%, which was 27.2% higher than the 29.4% of the downward borehole.

It can be seen from the comparison chart of the pure gas flow rate of the upper and lower boreholes in Figure 5 that the scalar amount of gas extracted from both the ascending boreholes and the descending boreholes is in a downward trend. After 140 days of drainage, the descending boreholes are draining gas. The scalar volume dropped to 0.085 m³/min; while the upward drilling, the scalar gas drainage dropped to 0.134 m³/min, especially after 70 days of drainage, the downward trend of the downward drilling scalar gas drainage was more obvious.

It can be seen that whether it is gas drainage concentration or gas drainage scalar, the drainage effect of the upward test hole is better than that of the downward test hole, which proves that the influence area of the upward drilling is larger than that of the downward drilling, which is more suitable for Baode Pre-pumping of mine gas.

6. Conclusion
(1) During the drainage test, the average gas concentration of the upward drilling was 35%, while the average gas concentration of the downward drilling was 30.87%, and the average extraction concentration of the upward drilling was 1.134 times that of the downward drilling; The average pure gas flow rate of the hole extraction is 0.12855 m³/min, the average pure gas flow rate of the downward drilling is 0.0992 m³/min, and the average pure gas flow of the upward drilling is 1.296 times that of the downward drilling.
The field test shows that under the same extraction unit and the same extraction process conditions, the effect of upward drilling in 81309 working face is better than that of downward drilling, which has a good application prospect, and also provides a practical basis for gas control measures under similar conditions.

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