

Experimental research on coalbed gas drainage effect and economy of long directional borehole in roof

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Abstract. In order to study the coalbed gas drainage effect and economy of long directional roof borehole, 2 boreholes were laid out in Xinji No. 2 mine to analyze its gas drainage and investment costs comparing with high position roof borehole and high position roof roadway. The result indicates that the long directional roof borehole save investment by 44.8% and shorten the construction period by 30% , comparing with high position roof roadway for controlling gas in the working face. Investment slightly less and shorten the construction period by 47.5%, comparing with the roof high position borehole. Therefore, the method of the long directional roof borehole to drain coalbed gas in working face is the most cost-effective.

1. Introduction

The mining-induced strata fracture field is excellent flowing channel of coalbed gas drainage. It is an effective way to control the gas limit by utilizing mining-induced fracture field to carry out gas drainage and control in working face and goaf.

At present, the common gas drainage methods used in coal mine underground roof crack field include the followings: roof high position drill, roof high position roadway and long directional roof borehole. The roof high position borehole method [1] has the characteristics of well-targeted, small construction quantities and operation relatively simple. But as working face of coal mining goes on and the roof falls, high borehole will be cut off, plugged or leaked, so there exists some defects including short extraction time, reduced utilization and so on. The high position roof roadway [2] has the characteristics of large extraction capacity and high extraction concentration. But the high drainage roadway is needed constructing before working face roadway for guaranteeing drainage of working face roadway and safety mining, and the roadway construction time is relatively long, construction and safety mining operation can't be carried out at the same time, which makes the shortage of mining face and increasing the mining cycle. Directional long roof borehole [3-5] has the characteristics of large amount of extraction, short construction period, low cost of extraction and so on. In addition, through the "borehole replace roadway", it reduces the amount of roadway excavation, borehole construction, mining operation which can be carried out at the same time and ease the mining face replacement tensions. Meanwhile, because the borehole is longer than conventional borehole, the concentration of gas extraction gets bigger and time of drainage gets longer.



Recently, along with the development of drainage equipment and directional drilling technology, the new technology of gas drainage with long borehole directional drainage gradually had been popularized [6]. Zhao [3] had been successful proposed long-bore directional gas drainage technology in the test, which provided a new way for gas control of high yield and high efficiency. Yao [7] proposed the development characteristics of strata pressure relief fractures in mining roof overburden coal seam, which made the difficulty of borehole orientation and construction gradually solved. However, it still needs to conduct in-depth analysis on the effect advantages of long borehole in roof, the difficulty of the project, the cost of extraction which compared with the traditional roof borehole and high roadway. In this paper, 210100 working face of Xinji No.2 Mine was tested with long directional roof borehole, and compared with other roof gas drainage methods from the aspects of extraction effect and economic factors, so as to provide guidance for popularization and application of the technology.

2. Gas drainage technology principle of long directional roof borehole

With the advance of working face, mining goaf around balance of original rock stress is destructed, the stress distributed, roof rock caving lead to overlying strata shear slip, separated or other forms of violent rock movement. According to the "masonry beam" mechanics model proposed by academician Qian^[8], the mining fracture field is divided into caving zone, roof fracture zone and bending zone in vertical direction. An annular mining fracture developing area is formed around the roof of the goaf, which is called "O" shape circle [9-10]. Under the action of mining induced stress, a large number of roof cracks develop, so that the permeability of coal seam is greatly improved, and the effect of increasing permeability and releasing pressure is obtained. The gas moving to goaf mainly come from mining coal seams, adjacent coal seams and goaf left coal, pressure released gas aggregate and move into mining fracture area, and finally gathered in the goaf roof mining fracture circle. Based on the above principle, through arranging long drainage borehole in the roof mining fracture "O" shape circle, and make the borehole always be in roof fracture zone, so orifice is always in the negative state, so we can make full use of the mining fracture channel to drainage.

3. The long directional roof borehole field test

3.1. General situation of the engineering

The test position is 210100 working face of the first mining area in Xinji No. 2 mine, coal seam Num. The coal seam 1 is majority. Working face coal seam thickness is on average 3.67m, coal seam solidity coefficient - is about 0.78 ~ 1.43, coal seam angle is between 1 ~ 10°, average of 6°, original gas content is 4.0m³/t, up to 12.46m³/t, and it is located in no outburst dangerous area. The roof is mainly sandstone, in which the old roof is fine sandstone, thickness is 15.3 ~ 24.7m, average of 21.7m, pseudo roof generally does not develop, direct roof is mainly medium sandstone, thickness is 6.7 ~ 8.0m, average of 7.3m.

3.2. Scheme of borehole layout

With conditions of coal seam occurrence and production technology of Xinji No. 2 mine, according to the coal seam overburden "vertical three zones" distribution theory ^[11-12], Xinji No. 2 mine Num.1 coal seam overburden "three vertical zones" distribution height respectively is: caving zone is 10.11m, fracture zone is 47.98m (including caving zone). Therefore, according to the height of caving zone and drainage practical research, we combined with the conditions of coal roadway layout work and then layout 2 roof long boreholes; the borehole depth was not less than 400m and 500m respectively. The specific location was shown in Fig.1~3.

Azimuth angle of opening borehole 1# was 122.45°, opening dip angle of 7°. Horizontal distance from 210100 working face return-air roadway was 12m, height from roof was 15~30m. Borehole depth was not less than 400m and terminal point through the open-off cut.

Azimuth angle of opening borehole 2# was 111.45° , opening dip angle of 8° . Horizontal distance from 210100 working face return-air roadway was 30m, height from roof was 30~40m, the main borehole terminal position arrived on the upper cut and constructed branch borehole behind 200m, the branch borehole moved towards machine roadway, the terminal borehole position distance to extracellular return-air roadway was 90m, the maximum depth of the borehole was not less than 500m, the branch borehole terminal position height from roof was 5-10m.

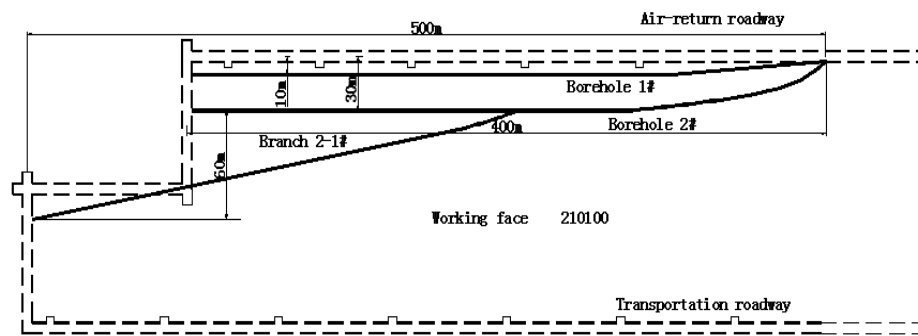


Fig.1 borehole Sketch of horizontal track projection

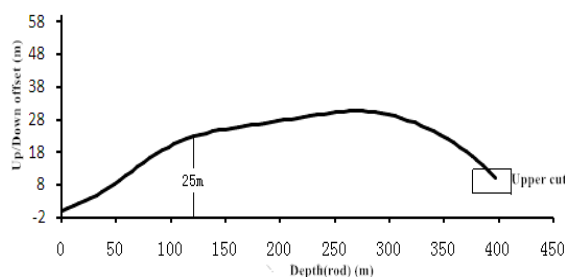


Fig.2 borehole 1# Sketch of track vertical profile

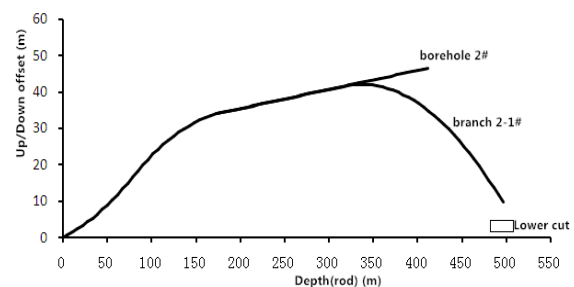


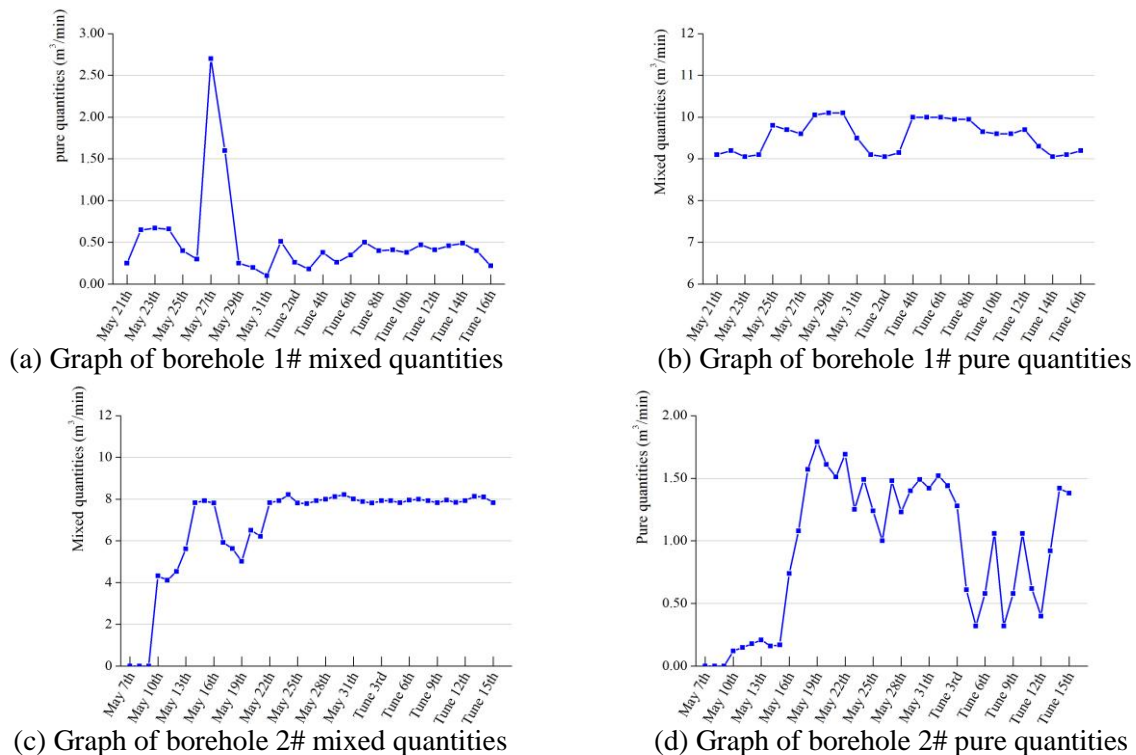
Fig.3 borehole 2#Sketch of track vertical profile

3.3. Effect of long directional roof borehole 1# and 2# gas drainage

The test time of borehole 1# was from May 7th, 2015 to June 16th, gas drainage monitoring was carried out in 210100 working face of 2 directional boreholes about 30d respectively, the borehole gas drainage effect as shown in Figure 4: during the test, from the beginning of May 21th, mixed gas drainage quantities of borehole 1# were between $9.09 \sim 10.23 \text{ m}^3/\text{min}$, which were average of $9.6 \text{ m}^3/\text{min}$, pure mixed quantities were between $0.17 \sim 0.69 \text{ m}^3/\text{min}$, and basically stable. The average pure quantities were $0.48 \text{ m}^3/\text{min}$, and the average extraction concentration was 5%.

Borehole 2# gas extraction data began to measure from May 10th, mixed gas drainage quantities were between $4.4 \sim 8.5 \text{ m}^3/\text{min}$, which were average of $7.84 \text{ m}^3/\text{min}$. Before May 18th, gas concentration of 2# borehole were less than 3%, pure quantities of drainage was less than $0.15 \text{ m}^3/\text{min}$. Since the beginning of May 19th, the concentration jumped to 11.7%, pure quantities jumped to $0.75 \text{ m}^3/\text{min}$, which were increased triple, before May 19th, pure quantity was between $0.75 \sim 1.82 \text{ m}^3/\text{min}$, from the beginning of May 19th, pure quantity rose significantly. Gas concentration rose to 21.39% on May 22th, pure quantity rose to $1.82 \text{ m}^3/\text{min}$. During the test, Average pure quantity was $1.18 \text{ m}^3/\text{min}$ and average drainage concentration was 15%.

Comparative analysis of drainage data indicated that the mixed quantities of borehole 1# were more than 2#borehole, however, the average gas drainage pure quantities of borehole 2# are about 2.4 times as much as borehole 1#, the average drainage concentration were 3 times as much as borehole 1#. The reason was that borehole 1# which was nearby air-return roadway leaked.

**Fig.4** Borehole gas drainage effect

4. Drainage comparison of long directional roof borehole, high position roof roadway and high position roof borehole

4.1. Basic situation

Compared between the same mining area roof gas drainage measures, there were mainly roof gas drainage following categories in mining area 2100: long directional roof borehole, high position roof roadway, high position roof borehole. Working face 210106, 210108 were arranged with high position roof roadway, and depth was 500m. Working face 210100, 210102, 210106 laid out high position roof borehole, a drilling field was arranged at intervals of 80m, arranged a total of 6 drilling field, each drilling field laid out 12 boreholes, and average depth of borehole were 120m. Mining face 210100 was arranged with long directional roof borehole 1#, 2#.

4.2. Comparative analysis of gas drainage effect

Roof gas drainage effect statistics of mining area 2101 are shown in figure 5. Compared with the other working face of mining area 2101, the proportion of directional borehole drainage quantities and absolute gas emission rate were all lower than working face in high position roof roadway and high position roof borehole, the main reason was the load flows of directional borehole were limited, thus if we increase the number of directional borehole and further optimize the borehole parameters to improve the drainage ability, it will be possible that the long directional roof boreholes replace high position roof roadway or high position roof borehole. The actual mixed quantities of two directional long boreholes in the test were above 7m³/min, however, considering the economic quantity, the average quantities of single borehole were 5.6m³/min. The mixed quantities of traditional high position roof borehole were 20m³/min. Therefore, to achieve the same effect, 4 directional boreholes were needed. The mixed quantities of high position roof roadway were above 30m³/min, 6 directional boreholes can meet the requirements.

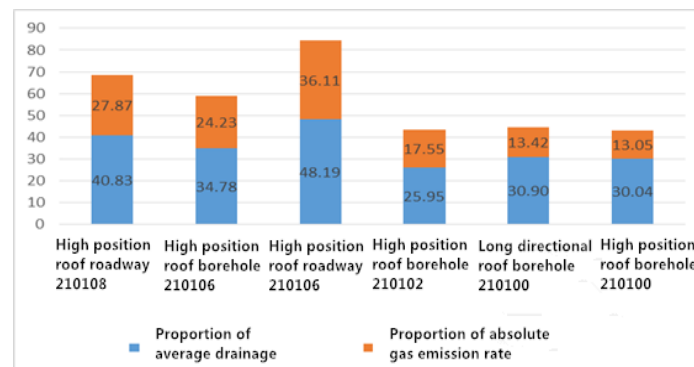


Fig.5 roof gas drainage effect chart in mining area 2101

4.3. Economic analysis

From the upper section, based on reaching the same gas drainage effect, 6 directional boreholes equal to high position roof roadway, 4 directional equal to high position roof borehole, and then analyze three kinds of drainage way of investment cost, time and human resources. The economy of these three methods were compared and analyzed. The statistical analysis of each gas drainage method is shown in Table 1. It can be seen from Table 1:

(1) In the same gas drainage effect conditions, laying out the long directional roof borehole of controlling gas which were compared to the high position roof roadway saved investment of 44.8%, shortened the construction period of 30%, and saved human resources of 28 people.

(2) In the same gas drainage effect conditions, laying out the long directional roof boreholes of controlling gas which were compared to the high position roof borehole nearly had not saved investment, but shortened the construction period of 47.5%.

In summary, laying out long directional roof borehole of controlling gas is cost-effective.

Table 1. Statistical analysis of each drainage method

Drainage measure	Unit price (Yuan/m)	Number of borehole or roadway	Footage (m)	Engineering cost (10K Yuan)	Engineering cost of drilling Field (10K Yuan)	Total cost (10K Yuan)	Human resources (People)	Time (Month)
high position roof roadway	8000	1	500×1	400	/	400	45	4.5
Long directional roof borehole	736	6	500×6	220.8	6.5	227.3	17	3.15
long directional roof borehole	736	4	500×4	153.7	6.5	153.7	17	2.1
high position roof borehole	163	12	120×12	140.832	15	155.832	16	4

5. Conclusions

(1) The development of roof fractures under mining-induced stress provides channels for gas flowing of coal seam, increased roof permeability and decreased pressure. Meanwhile, destressing gas concentrated in the "O" shape circle, the formation of a series of favorable conditions will promote gas drainage effect in roof.

(2) Field test result indicates that in the same gas drainage effect conditions, the long directional roof borehole saved investment by 44.8% and shortened the construction period by 30% which compared with high position roof roadway for controlling gas in the working face, and investment slightly decreased and shortened the construction period by 47.5% which compared with the high position roof borehole. The arrangement of the long directional roof borehole to control gas in working face was cost-effective; it had achieved safety and efficient production in Xinji No. 2 mine working face 210100.

(3) As a new gas drainage method, roof directional long borehole has high drainage efficiency, low investment funds, and short construction period, which compared with the traditional coal seam roof gas drainage method. It will have greater application prospects.

Acknowledgments

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