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Influence and control effect of drawing speed on mining-induced fractures "O" form circle's fully mechanized surface

Based on the theory of key stratum in ground control, a theoretical model is established in which the governing equation of the "O" form circle is exported and a 2D model of the mining-induced fractures "O" form circle is established. Based on the geological conditions of the Yuelt Coal Mine of the Panj Group, a numerical simulation study of the mining-induced fracture "O" form circle is carried out by Ansys. According to the conclusion, the range of the mining-induced fracture "O" form circle decreases with the advancing speed of the working surface and the development of the gas channel. Therefore, the design parameters of high drilling are optimized with the higher working surface drawing speed and the "O" form ring development degree decline, and a high drilling gas drainage test is carried out in Yuelt Coal Mine No.131015's working surface. The experimental results show that the optimization of the high drilling parameters is reasonable, and also confirms the influence and control effect of the drawing speed on the mining-induced fractures "O" form circle.

Keywords: *Mining-induced fractures "O" form circle, drawing speed, high drilling, gas drainage.*

1. Introduction

Coal mine gas disasters are one of the main disasters that affect the safety of coal mine production. With the increase of the depth of coal mining in our country, the mine pressure is increasing, and coal and gas disasters are becoming more and more serious. According to Chinese standards such as the "coal and gas outburst prevention and control regulations" requirement [1], regional gas control has priority in the use of protective layer mining technology. But the protection layer after the mining overlying strata movement will lead to the gradual development of mining fissures from bottom to top. The final mining fissure formation in the overlying strata within the fractured zone with the working surface also advances continuously, resulting in a continuous influx of working surface gas pressure on the relief coal seam. This poses a serious safety threat; therefore, the protection of the safe mining working surface necessitates core-layer protection layer mining. To this end, the "coal mine gas extraction standards interim provisions"[2] will be taken as the main source of gas recovery from the adjacent layer of coal mining surface gas emission index of the effect of extraction. The practice shows the gas drainage from the top of the roof to the high position. The high position is one of the main technologies of coal mine gas control because of its advantages such as simple process, large amount of extraction, low cost, and wide application [3-4]. Research has found that the overlying strata of mining fissure zones show different gas concentrations; to improve the gas drainage rate, the final hole or high roadway requires drilling in the fractured zone in the gas enrichment area, which is located in the mining fissure type "O" form circle, to achieve efficient pressure relief gas drainage.

In recent years, there has been a lot of research on changing characteristics and morphology around the overlying strata after mining moving [5-11]. Finding the development scope and evolution of the work surface fissure "O" form ring speed is closely related to the working surface advancing faster. The time for a crack to develop is short, but the maintenance time for the "O" form ring is even shorter [12]. Studies on the influence of the working surface advancing speed on the temporal and spatial distribution characteristics of the mining fissure "O" form ring show the lack of systematic and qualitative processing and the lack of a theoretical basis for the design of a high-level borehole, and are mostly based on experience. These shortcomings seriously hinder the development of pressure relief gas drainage technology; therefore, in order to improve the gas drainage effect, in-depth research is needed to study the different speeds of the overlying strata of the mining fissure "O" form ring evolution, and obtain a variation of the mining fissure "O" form ring with a working surface advancing speed.

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In this paper, the different surface advance speed under the influence of the mining fissure "O" form ring and the control effect for different working surface advancing speeds of pressure relief gas drainage are studied in Panj Group's Yuelt coal mine, and the extraction technology optimization design provides a theoretical basis.

2. Spatio-temporal distribution of mining-induced fractures "O" form circle

2.1 Theoretical model of spatio-temporal distribution of mining-induced fractures "O" form circle

Coal mining will crack and fracture and lead to a vertical separation of two kinds of [13] in the formation of overlying strata in. The corresponding separation cracks can be divided into two stages. The first stage is from the beginning of the cut; with the advance of the working surface, the abscission fracture also increases, and in the center of the goaf it is most developed. The second stage entails a decrease of the goaf middle separation rate, until it tends to be compacted, and both sides still maintain the development trend of the fracture. When the working surface advances after a certain distance, the goaf in the basic layer cranny is compacted, and around the existing development zones through a fissure, we call the mining fissure the "O" form ring, as shown in Fig.1(a). The mining fissure "O" form ring in the coal and rock pore is large, and has ventilation ability, and is the main channel of air leakage on the coal mining surface. According to the research of Minggao Qian, it is simplified into a two-dimensional coordinate model, as shown in Fig.1(b). The "O" form ring of the control equation can be obtained as follows:

$$\frac{\left(x-\frac{A+a_1-a_2}{2}\right)^2}{\left(\frac{A-a_1-a_2}{2}\right)^2}+\frac{\left(y-\frac{B+b_1-b_2}{2}\right)^2}{\left(\frac{B-b_1-b_2}{2}\right)^2}=1 \quad \cdots \quad (1)$$

In the formula, B is the length of the working surface, m; A is the working surface n days' cumulative advance distance, $A=\sum v_i t_i$, m; v is the working surface advancing speed, m/t; t is the time, d. b_1 and b_2 are the "O" form ring intake side and tailgate width, respectively; a_1 and a_2 are the "O" form ring working surface; m is the cutting of the width.

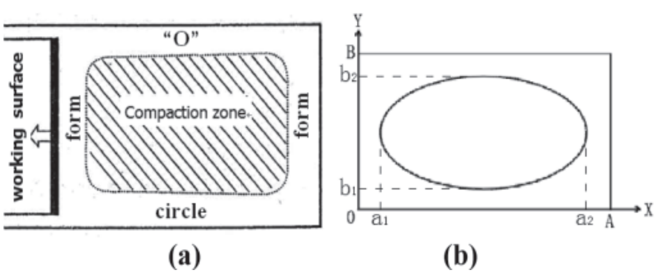


Fig.1 Distribution of the mining-induced fractures "O" form circle diagram

2.2 Dynamic evolution process of mining-induced fractures "O" form circle

With the advance of the working surface, the mining fissure zone undergoes a dynamic development. Therefore, the mining fissure "O" form ring is constantly changing, and the evolution process is shown in Fig.2. Its dynamic evolution is influenced by many factors, such as rock formation, coal seam dip angle, the speed of the working surface, coal mining methods, roof management, mining procedures and time factors, etc.[14]

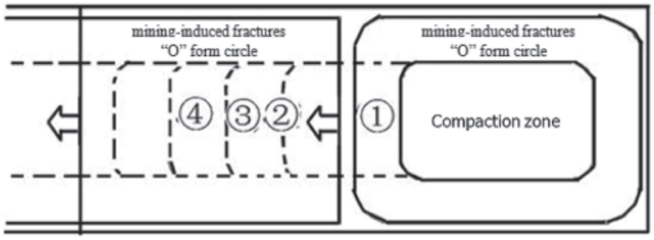


Fig.2 Evolution process of mining-induced fractures "O" form circle

2.3 Influence and control of working surface propulsion speed on mining-induced fractures "O" form circle

In order to understand the development of the "O" form ring in the mining of the fully mechanized coal mining surface, the authors provide the basis for the artificial gas drainage measures such as high drilling and high lanes. The similarity simulation software A is used to obtain the evolution process of the "O" form ring at different propulsion speeds of the working surface. At present, the depth of the fully mechanized mining drum shearer is 0.6m~0.8m and the propulsion rate is 2~6m/d. Taking the speed of 2m/d as the traditional working surface, 6m/s as the high speed of the working surface, and 4m/d as the contrast, the authors studied the development characteristics of the "O" form ring under different propulsion speeds. The "O" form ring is basically stable after the 130m is advanced in the working surface, and the range of the "O" form ring decreases as the propulsion speed increases, that is, a_1, b_1 decreases. In this paper, the spatial distribution patterns of the mining-induced fractures "O" form circle are obtained at 2m/d, 4m/d, and 6m/d respectively, as shown in Fig.3. At the same time, the degree of separation of the inside of the "O" form ring is described, and the change of the velocity of the working speed is shown in Fig.4.

Research shows that with the working surface advancing speed continuing to accelerate, the overlying strata in mining fissures of the working surface advance the longer distance to stabilize, and will lead to the mining fissure "O" form ring showing different development characteristics.

(1) At the same distance, with increasing speed, the scope of the mining fissure "O" form ring becomes smaller. This is due to the accelerated speed of the resulting overburden that appears in the cantilever structure, making the "O" form ring growth degree lower and its range smaller.

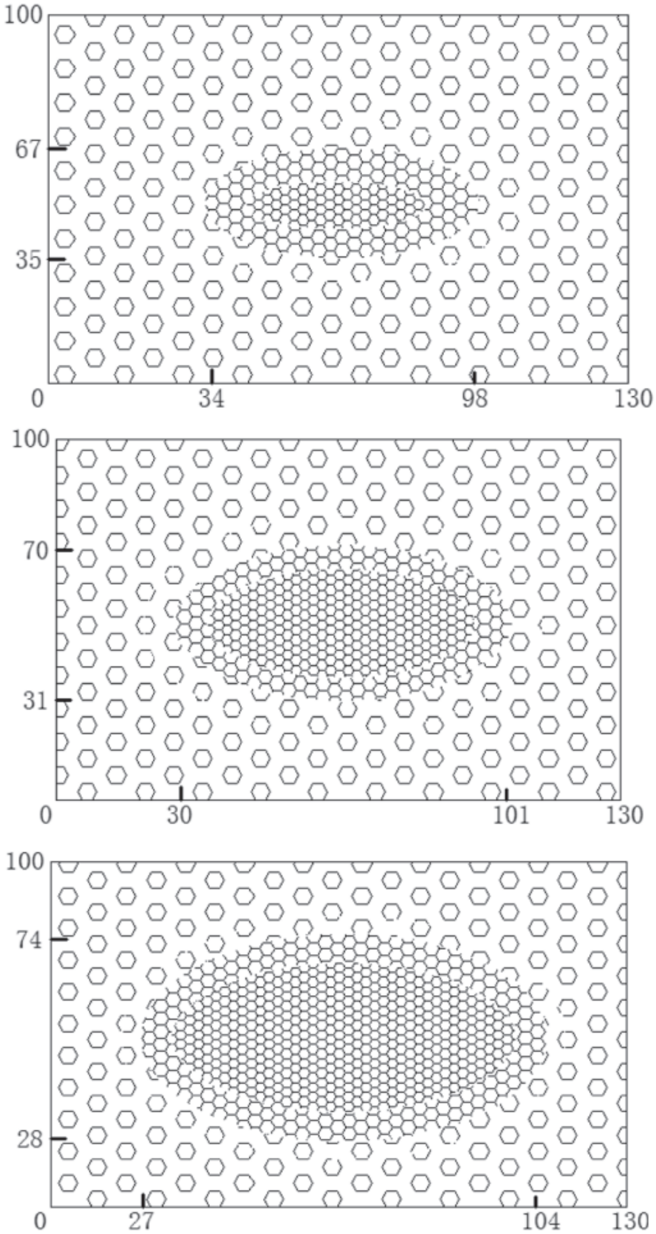
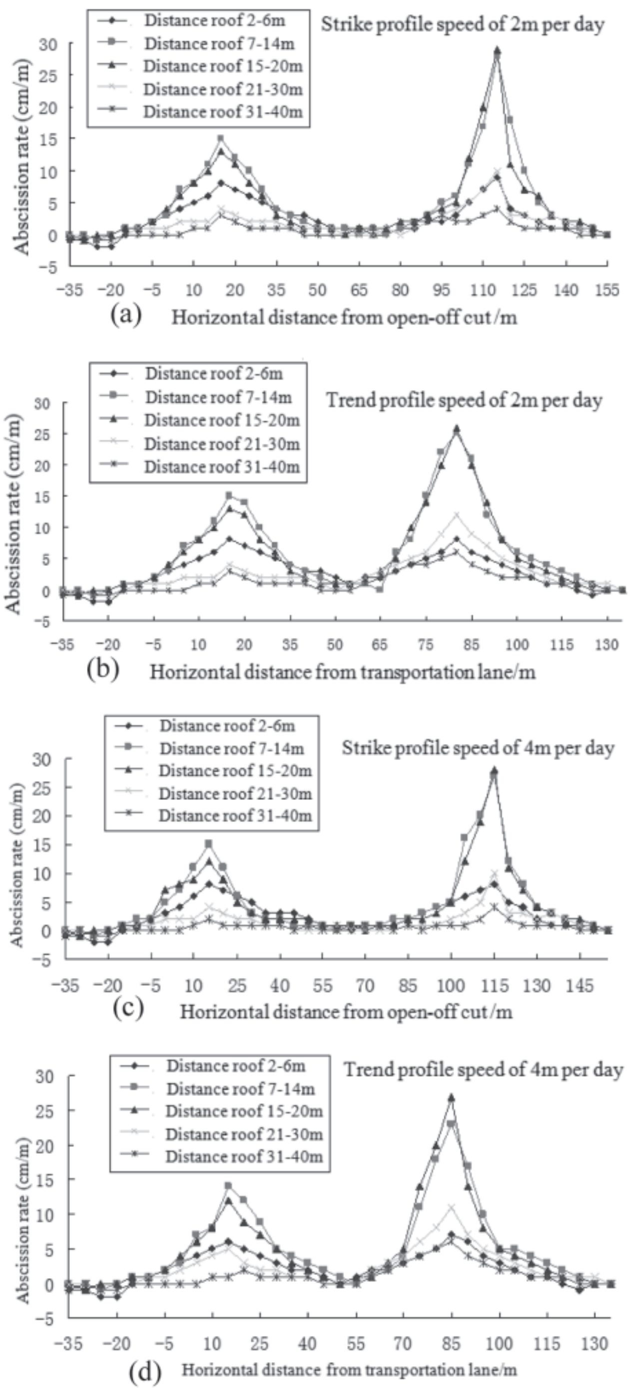


Fig.3 Spatial distribution pattern of the mining-induced fractures "O" form circle diagram with drawing speeds of 2, 4, 6 m/d

(2) If one pushes the distance to 130m or so, the "O" shape tends to be stable. When the speed increases from 2m/d to 4m/d, 6m/d to promote the work surface, Figs.3(a) (b) (c), Figs.4 (d) (e) (f) show that in the direction of the working surface, the side "O" form ring width is reduced by about 34m to 30m, 27m, and the opencut by the side width of about 32m is reduced to 29m, 26m. Figs.3 (a) (b) (c), Figs.4 (d) (e) (f) show that in the dip direction, the transportation tunnel "O" form ring width of about 35m decreases to 31m, 28m. The return air side "O" form ring width of about 33m is reduced to 30m, 26m.

High drilling has been widely used in recent years and the high drainage roadway is the circulation channel utilization of the mining fissure "O" form ring, a rock with a high permeability zone that is rich in gas and boasts the advantages of the influence and control of gas flow. The gas drainage in the fractured zone of artificial mining effectively prevents gas in the goaf and upper corner of the working surface. In order to realize the efficient extraction of gas, a high drilling hole and the end of the roadway should be located in the mining fissure "O" form ring. It can be concluded that, when the speed is increased to promote the



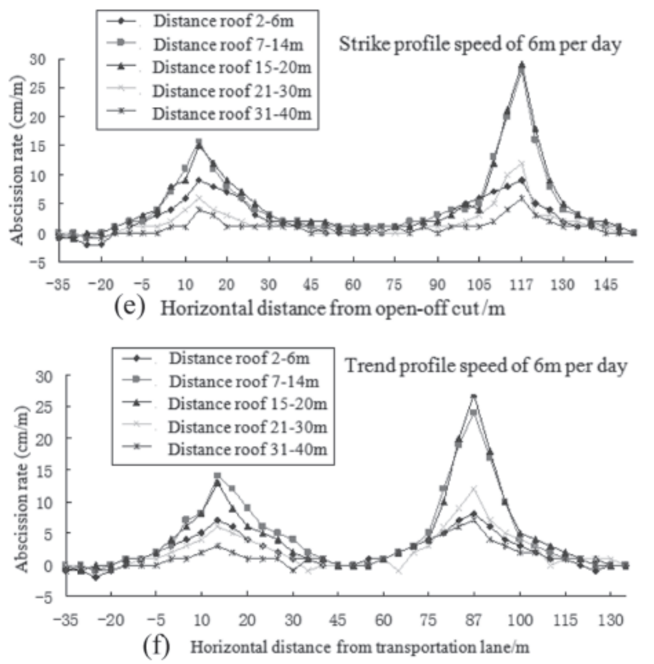


Fig.4 Curves of overlying strata separation rate at the pane advancing 120 m with drawing speeds of 2, 4, 6 m/d

work surface, the “O” form ring of the smaller gas passage development decreases; therefore, high drilling parameters and high layout lane parameters should be changed, otherwise they will not effectively control the crack zone gas flow state. A less efficient extraction cannot completely solve the gas overrun problem in the goaf, the working surface, and the upper corner.

3. Field test of pressure relief gas drainage in mining-induced fractures “O” form circle

In order to verify the obtained speed effect on the mining fissure “O” form ring and control law, an “O” form ring pressure relief gas drainage test was carried out in the south mining area of the Yuelt coal mine’s fully mechanized surface.

3.1 Overview of study region

The study region is No.131015’s coal surface in the 10# layer south mining area; the direction of the working surface length is 865m, the inclined length is 168m, the average angle is 11 degrees, the average height is 2.8m. The 6# coal seam (No.13617 mining surface) is one of the adjacent layers of the 10# coal seam. The pressure relief gas will flow into the surface of the No.131015 coal mine, which will seriously affect the safe mining of the 10# coal seam. The gas pressure (absolute gas pressure) of the 10# layer is 1.2MPa~2.1MPa, the gas content is $14.07m^3/t$, and the permeability coefficient of the coal seam is $0.0489m^2/(MPa^2.d)$. In order to prevent the influx of gas caused by the gas from the adjacent seam and goaf during mining, during the mining period, a pumping roadway will be installed at the top of the working face. According to the No.131015’s working face layout of the high field drilling for induction, then controlling gas emission in goaf.

The 10# coal seam's geological structure is complex, as there are a large number of folds, faults, and so on. In July, in the No.131015 coal mine the high drilling speed by 2m/d design promoted the final hole drilling position from the roof by 24~28m. Thirty days later, the working face advancing speed was adjusted to 4m/d, and the results showed that the gas drainage effect on the top hole was poor, and the gas concentration in the upper corner of the working face was overrunning. Therefore, 90 days later the engineer in charge of the advance design parameters optimized the high drilling speed, and changed the distance of the high drilling hole to the coal seam roof from 24~28m to 16~20m. The final hole spacing was 12m and the tailgate high-field drilling field spacing was 100m, with each playing 8 holes, divided into two rows. Each row has 4 holes.

Afterwards, the influence of different propulsion speeds on the position parameters of the high drilling hole was tested: In October, the advancing speed of the working face was increased to 6m/d, and the effect of the extraction was found to be worse. Moreover, the gas concentration in the upper corner of the working face was overrunning. In November, engineers changed the distance of the end high drilling hole to the coal seam roof from 24~28m to 16~20m, while the other parameters remained unchanged.

3.2 Analysis of artificial control effect of pressure relief gas

In order to verify the correctness of the high drilling parameters optimized according to the different propulsion speeds, the high-level borehole gas drainage in the 10# coal seam surface was measured in September. Due to limited space, this paper only selected 5 drilling field analyses. The drill floor drilling parameters are shown in Table 1. The relationship between the concentration of borehole gas drainage and the distance between the drill field and the working face are shown in Fig.5. The relationship between the gas extraction concentration and the distance between the final hole drilling and the air return roadway are shown in

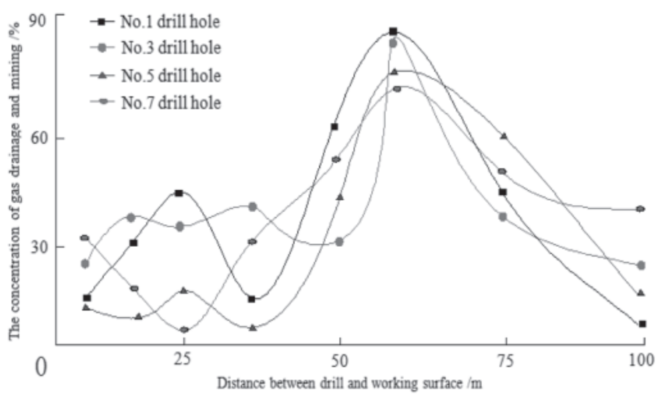


Fig.5 Relationship between the concentration of borehole gas drainage and the distance between the drill field and the working face

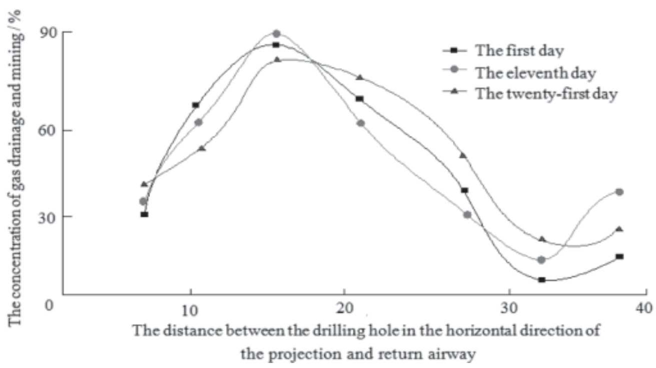


Fig.6 Relationship between the gas extraction concentration and the distance between the final hole drilling and the air return roadway in September

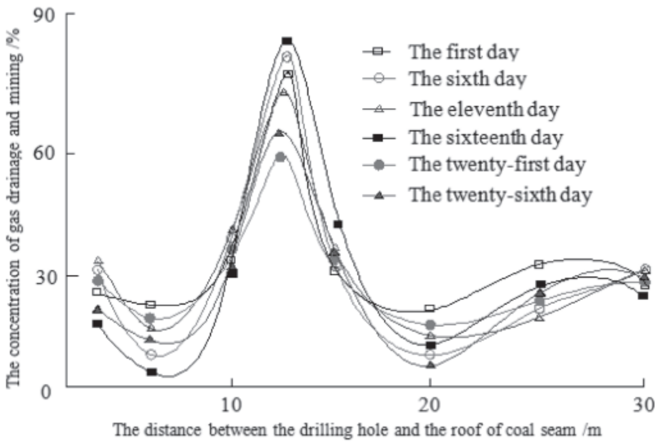


Fig.7 Relationship between the gas extraction concentration and the distance between the final hole drilling and the coal seam roof in no.5 drilling field in September

Fig.6. The relationship between the gas extraction concentration and the distance between the final hole drilling and the coal seam roof are shown in Fig.7.

Analysis of any 4 drill holes in drill 5: According to Fig.5, in the Nos.1, 3, 5, 7 drilling fields, the drilling of the gas drainage concentration increases first and then decreases with the increase of the distance from the working face. Overall, when drilling from the working surface of 40~85m, gas extraction concentration is above 30%, indicating that a distance from the coal seam roof in the 16~20m range is developed after the final hole drilling adjustment in the mining fissure “O” form ring. When the drill field distance from the working surface is less than 40m, the gas drainage concentration will decrease rapidly because of the roof fracture caused by drilling dislocation and collapse.

Starting from September 1, take one day every 10 days, as shown in Fig. 6. The final hole drilling in horizontal projection and return air roadway distance are 7~28m, and the concentration of gas mining is more than 30%, indicating the high-end drilling holes in a horizontal projection location from the return air lane in the range of 7~28m are conducive to the improvement of gas extraction concentration.

From September 1, take one day every 5 days, as shown in Fig.7. The high-end drilling hole distance to the seam roof vertical distance is 10~15m, and the drilling field gas drainage concentration is above 30%, which can be inferred from the coal seam roof strata of the 10~15m channel, which is the mining fissure “O” form ring. A final hole drilling in the region can achieve the ideal gas drainage effect. In view of the high roadway drilling of gas drainage, the gas concentration of No.131015 tail entry is basically controlled at 0.24%~ 0.59%; the concentration of the upper corner is 0.42%~0.85%. The utility model eliminates the problem of gas overrun in the working face and the upper corner, realizing an efficient and safe mining working surface.

In sum, the advance speed (4m/d) and the optimized parameters used at No.131015 Yuelt coal mine’s surface are reasonable. Because of the limited space, the speed was adjusted again in November (6m/d), but the same analysis was no longer carried out. The gas concentration in the return air lane is basically controlled at 0.32%~0.65%, and the concentration of the upper corner control is 0.53%~0.91%. This optimization is very reasonable.

TABLE 1: CONSTRUCTION PARAMETERS OF HIGH POSITION BORING AT NO.5 DRILLING FIELD

	Azimuth /(°)	Inclination /(°)	Drilling hole in the horizontal direction of the projection distance from the return airway/m	The distance from the final hole of the borehole to the roof of the coal seam /m	Hole deep /m
1	Left 4.8	4.4	8.5	11.8	98.2
2	Left 8.1	8.6	13.6	9.3	112.5
3	Left 11.4	5.3	15.8	18.4	107.3
4	Right 3.6	6.6	30.5	20.6	89.9
5	Right 7.9	5.9	23.4	16.6	95.4
6	Right 10.7	7.7	35.6	8.1	103.5
7	Right 13.6	8.5	21.1	14.7	115.1
8	Right 17.5	6.9	28.5	16.5	100.6

Note: The azimuth angle is 0° reference for return airway.

4. Conclusions

(1) Based on the key strata theory of strata control, a two-dimensional model for the mining-induced fractures "O" form circle is established, and the control equation of the "O" form circle is derived, which provides the theoretical basis for the effect and control of the mining-induced fractures "O" form circle.

(2) In this paper, the south mining area of the Yuelt coal mine serves as the prototype, and the fluid simulation software Ansys is used to carry out numerical experiments on the overlying strata mining fissure "O" form ring. The influence and control effect of the advancing velocity on the mining-induced fractures "O" form circle are obtained. It is concluded that the range of the mining-induced fractures "O" form circle decreases with the acceleration of the working surface and the development of the gas channel decreases as well. The results show that when the working surface has advancing speed, the development degree of the "O" form circle decreases, and the parameters of the high drilling hole should be adjusted accordingly.

(3) Using the Yuelt coal mine No.131015's working surface as the research area, a high-level borehole gas drainage test is carried out. The results show that the optimization of the high drilling parameters of No.131015's working face with different propulsion speeds is reasonable. The results also indicate that the influence and control effect of the advancing velocity on the mining-induced fractures "O" form circle are correct and reasonable, and can provide a theoretical basis for the optimization of the working surface advancing speed change after gas drainage technology.

Acknowledgment

This work is supported by Science and technology department joint fund project of Guizhou province (Grant No.LH[2014]7484); Tongren University doctoral research fund project (Grant No.trxyDH1623).

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