Study on Gas Drainage Technology in Goaf of Steep Seam

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Abstract. Aiming at the problem of gas control in the upper corner of steeply inclined coal seam, taking 3103 working face of a mine as an example, this paper determines the height range of fracture zone by combining theoretical empirical formula with on-site investigation of microseismic monitoring technology, designs the parameters of drainage borehole during production, and analyzes the gas drainage effect of long-strike borehole through on-site experiments. The results show that the average gas extraction concentration of the long borehole along the strike of 3103 working face is 53.55%, and the average gas extraction purity is 5.37 m³/min. After treatment, the gas concentration in the upper corner is about 0.4%, and the concentration in the return air roadway is about 0.3%, which ensures the control effect of gas extraction quantity.

1. Introduction

The upper corner of the working face is easy to form a gas gathering area, which is a major threat to the safe production of the working face.[1,2]. This problem has always been a difficult problem in coal mine gas control, and it is also the focus of high efficiency production research in coal mining face at present. At present, the underground gas control means are buried pipe drainage.[3–6], high pumping roadway drainage[7–10]High-level borehole drainage[11–13]Wait. The method of gas drainage by buried pipe in goaf is simple, but the drainage effect is poor because of the large air leakage between supports. The traditional high-level borehole has the advantages of short effective drainage time, large number of boreholes, large engineering quantity and low economic benefit. The drainage effect of long-strike borehole is mainly controlled by the arrangement of horizons, but the field application is mostly subjective and empirical, so it is particularly important to choose appropriate field investigation methods to optimize the hole arrangement parameters. Many coal mines have applied strike long drilling technology to gas control in the upper corner, and achieved remarkable results. Xu Shiqing[14]By means of numerical simulation and theoretical calculation, the layout parameters of high-level drilling holes are optimized, and gas drainage in long-distance goaf is realized. Zhang yachao[15]The model of "high-position drilling and walking buried pipe drainage in upper corner" proposed by others can effectively control the problem of gas overrun in upper corner and ensure the normal production of coal mining face. Wang Haidong[16]Aiming at the problem that the upper corner frequently exceeds the limit, the gas drainage technology of long borehole with large diameter strike on the roof is put forward, and the drilling parameters are optimized by FLAC3D.

Steep coal seam in China[17,18]Although rich in resources, due to its special geological structure, the stress of coal and rock mass around the goaf is redistributed, and the mining fracture zone is asymmetrical, which provides a new migration channel for gas, resulting in a certain range of pressure-relieved gas threatening the normal construction of the working face during mining. Therefore, it is difficult to conduct on-site investigation and gas control in the fracture zone of steep coal seam. Aiming at the special geological conditions of steeply inclined coal seam and the limitations of traditional drilling technology, this paper takes the 3103 working face of a mine as an example, and combines microseismic monitoring technology with theory to investigate the development height of fracture zone and optimize drilling parameters, so as to investigate the treatment effect of long-strike drilling.

2. General situation of the project

2.1 General situation of working face

3103 south working face is the third section of 31 mining area in a mine. The average inclined length of the working face is 135m, the dip angle of coal seam is 48, the average thickness is 2.3m, the elevation of transportation lane is+301.8 m ~+322.4 m, the elevation of return air lane is+402.3 m ~+421.6 m, and the surface elevation of the working face is+855 m ~+1020 m. The direct roof of regional coal seam is gray-black mudstone with a thickness of 14.5m, sandwiched with sandy mudstone and limestone, and the hardness coefficient is 3 ~ 12. The basic roof is dark gray limestone with an average thickness of 15.05m, and the upper part is sandwiched with a layer of gray-black mudstone with a hardness coefficient of 8 ~ 12.

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2.2 Gas occurrence

3103 south working face is at the elevation of+305 m ~+415 m, the original gas pressure of coal seam is 3.22 ~ 3.60 MPa, and the initial content is 14.39 ~ 19.8 m3/t. After the implementation of regional comprehensive air defense measures, the measured maximum residual gas content in coal seam is 4.96m3/t. Through on-site measurement and analysis, the gas in the working face mainly comes from this coal seam. Because floating coal and coal pillars gush out a large amount of gas into the goaf, it then spreads to the working face and is carried out by airflow, which causes gas accumulation in the upper corner.

3. "Three Zones" Height Field Survey

In recent years, microseismic monitoring technology[19,20]It is widely used to monitor the energy generated by rock burst. When the coal and rock mass breaks, it is transmitted to the sensor through the medium in the form of electrical signals, and the location and energy of microseismic events are obtained, so as to determine the distribution and trend of mining fractures, and then analyze the height range of fracture zone.

3.1 Arrangement scheme of microseismic monitoring instruments

Microseismic monitoring technology is adopted in this field investigation. The instrument includes sensors, collectors and cables. The instrument is shown in Figure 1.

Fig 1.Microseismic monitoring instrument

There are 4 acquisition instruments and 12 sensors in the working face. Two collectors and six sensors are set in 3103 South Transportation Lane and 3103 South Return Air Lane respectively, with the serial numbers of 1 ~ 6. The leading working face of the sensors is 50m for the first time, and the sensor spacing is 50m. The arrangement of the instrument is shown in Figure 2.

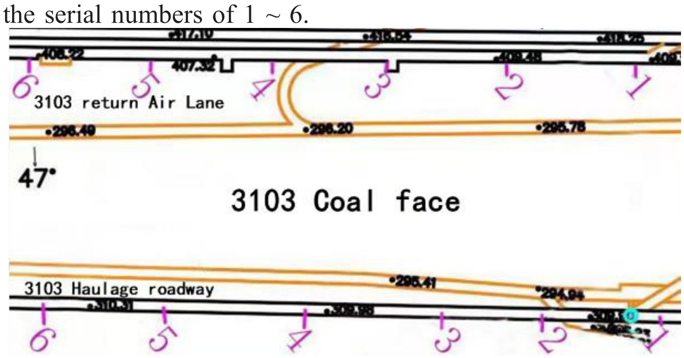


Fig 2.Microseismic sensor arrangement

By reasonably arranging the working hours of instruments and personnel, high efficiency and uninterrupted operation can be realized. These include sensor placement, shift monitoring and data collection. The specific steps are as follows:

(1) The position of the measuring point shall be determined when going into the well for the first time, and the geodetic coordinates shall be measured by ground surveyors. The measuring points are arranged 50m away from the advanced working face, with a spacing of 50m and a length of 300m.

(2) Due to the power limitation of the acquisition equipment (charging for 8 hours), if 24-hour continuous monitoring is needed, the acquisition equipment should be replaced twice a day, at 8 am and 24 pm respectively. There are 8 acquisition instruments in total, which are divided into two batches, one for underground monitoring and the other for charging in the well. According to the size of the label, it is arranged in the inlet and return air roadway respectively.

(3) In the process of monitoring, it is necessary to record the time period, corresponding measuring point number and acquisition instrument number for later data processing.

3.2 Monitoring data processing

Microseismic monitoring data processing is mainly a series of data processing processes such as microseismic event extraction, filtering, positioning and three-dimensional display. Among them, the extraction and location of microseismic events is the key step. The ultimate goal of data processing is to locate microseismic events, so as to obtain the range of coal seam roof fracture. Combined with the coordinates of effective microseismic events, the microseismic events are arranged on the inclined profile, and the vertical distance between the source and the coal seam is determined, as shown in Figure 3.

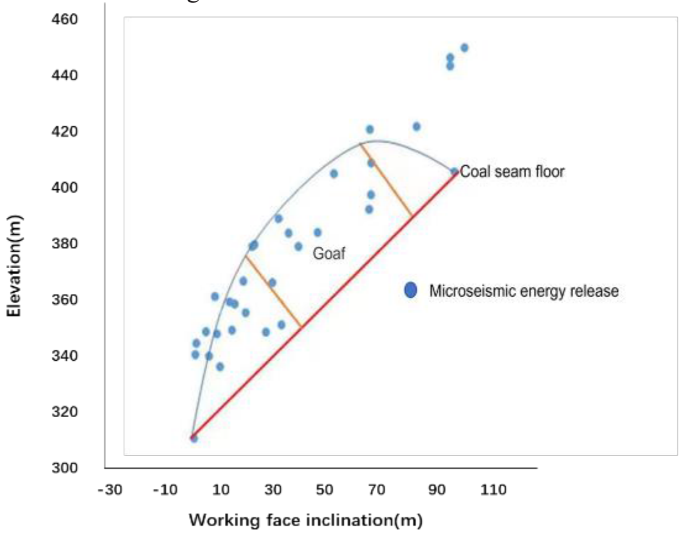


Fig 3.Distribution of microseismic source in inclined section of coal seam

According to the analysis in Figure 3, the maximum height, minimum height and average height of larger microseismic events are 34.2m, 6.8m and 23.6m respectively.

3.3 Comparison of monitoring results

According to the parameters obtained from the roof of the working face, the rock stratum is medium hard overburden. Referring to the empirical formula in the Manual of Fully Mechanized Mining Technology, the formula for selecting the height of caving zone and fracture zone is calculated. Caving zone height of mined-out area is calculated by Formula (1):

$$H_M = \frac{100\sum M}{4.7\sum +19} \pm 2.2 \qquad (1)$$

Among them, it refers to the height of caving zone in goaf, and m refers to the working coal seam thickness of 2.3m. It is calculated that the height of caving zone in goaf is 5.5-9.9m, with an average of 7.7m.H_M

The height of fractured zone in goaf is calculated by formula (2):

$$H_L = \frac{100\sum M}{1.6\sum +3.6} \pm 5. \qquad (2)$$

Among them, it refers to the height of fracture zone in goaf. It is calculated that the height of fracture zone in goaf is 26.0-37.2m, with an average of 31.6m m.H_L

The fracture zone of goaf obtained by microseismic monitoring ranges from 6.8 m to 34.2 m, which is consistent with the calculation results of theoretical formula, indicating that the results obtained by microseismic monitoring are reliable.

4.Gas control scheme of 3-strike long borehole

For the problem that the gas in the upper corner of 3103 working face is at high risk of exceeding the limit, the initial measure is to construct a high-caving drainage hole to the working face, but this method has the disadvantages of short drilling time, large engineering quantity and unsatisfactory drainage. According to the investigation of the height range of fracture zone and the coal seam conditions, the gas drainage in the upper corner is carried out by drilling holes with long strike. Because the borehole is arranged in the "O" ring of the goaf crack, the pressure relief gas in the roof crack flows into the borehole under the negative pressure of drainage, and the gas accumulated in the upper corner is pumped out, thus achieving the effect of gas control in the upper corner.

4.1 Drilling arrangement

Reasonable horizon arrangement can effectively avoid the occurrence of cave-in caused by rock failure and caving. According to microseismic monitoring technology, the range of fracture zone is 6.8～34.2m m. Three boreholes are arranged in the drilling field according to the inclined direction, and the boreholes are arranged in the interbedded sandstone and mudstone on the roof of coal seam in turn. The cross-sectional view of the arrangement of boreholes along the inclined direction is shown in Figure 4. The inclination angle of drilling hole is 13, the distance between drilling hole and roof normal is 33m, the spacing between drilling holes is 10m, the aperture is 120mm, and the drilling depth can reach 500m. The drilling construction parameters are shown in Table 1.

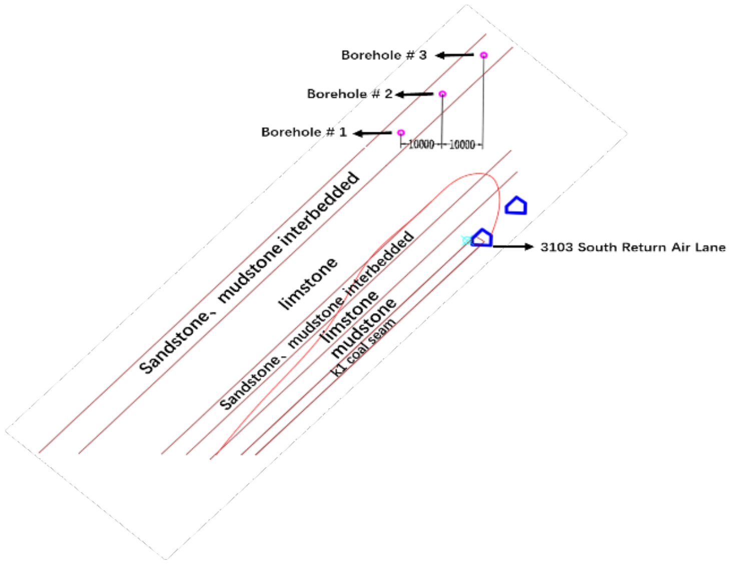


Fig 4.Cross-sectional view of inclined arrangement of drilling holes

Table 1.Parameters of each borehole

Borehole number	Distance from roof normal /m	Main hole orientation/()	Inclination angle of opening/()	Azimuth/()	Drilling depth /m	Borehole diameter /mm
1#	33	218	12.5	212.5	350	120
2#	33	218	13	205	500	120
3#	33	218	13	199	350	120

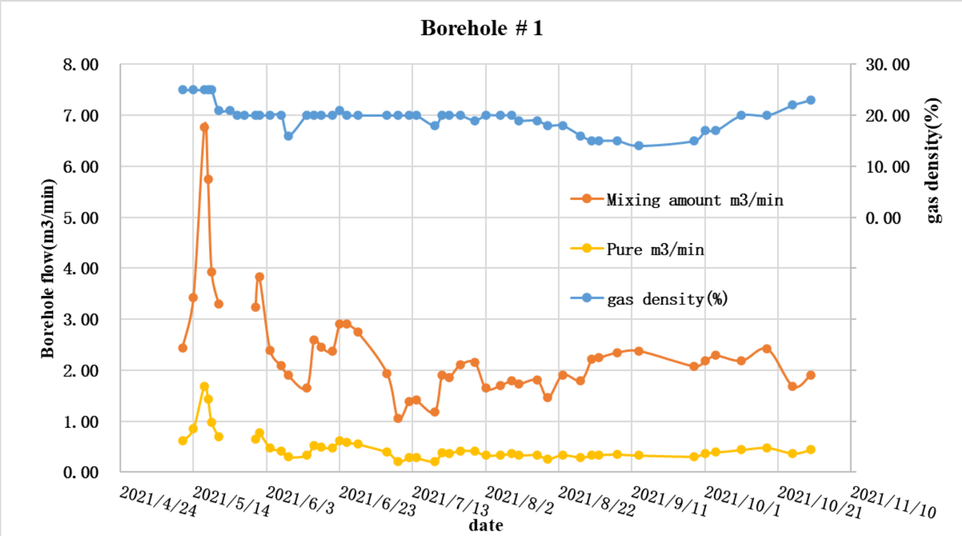
4.2 Drilling Technology

A set of ZDY6000LD(B) underground directional hydraulic crawler drilling rig was used for the construction of this drainage drilling. According to the design parameters (inclination angle and azimuth angle) of drilling hole, the drilling rig was stabilized, and the φ Φ120mmPDC flat-bottom bit+φ 89 mm drill pipe rotary drilling process was used to drill the 12m hole, and then the φ Φ153mm reaming bit+φ 89mm drill pipe reaming was used for 6m. The drilling sequence is to construct 2# hole first and achieve the design goal, and design and construct 1# and 3# holes according to the hole-forming data.

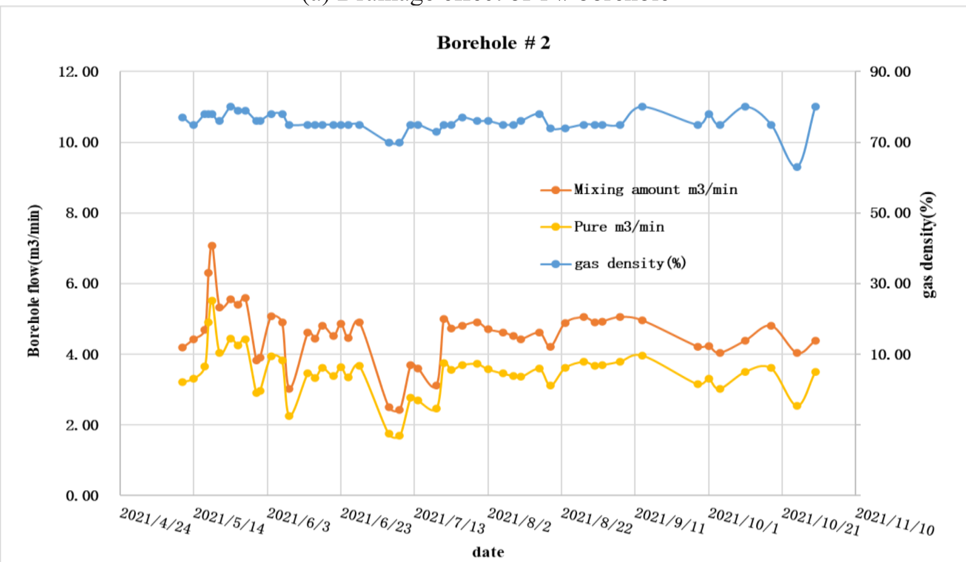
4.3 Gas drainage effect analysis

4.3.1 Analysis of Drilling Effect

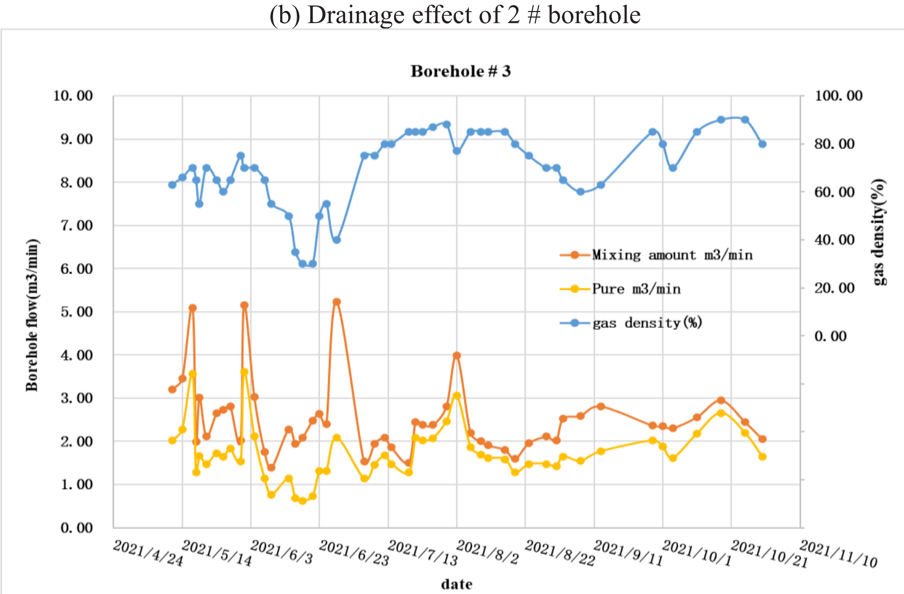
In order to investigate the drainage effect of long boreholes along the direction of 3103 working face in steep seam, flow monitoring equipment was installed at each borehole, and some gas drainage data were selected. Now, the gas drainage purity, drainage concentration and drainage mixture of each borehole during the advancing process of 3103 working face are sorted out in detail and analyzed by drawing curves, as shown in Figure 5.



(a) Drainage effect of 1 # borehole



(b) Drainage effect of 2 # borehole



(c) Drainage effect of 3 # borehole

Fig 5.Drilling and extraction effect

As can be seen from Figure 5(a), the gas drainage data of 1# borehole has a small growth range, the gas drainage purity is stable between 0.3 and 1 m/min, and the maximum gas drainage concentration is only 25%. Compared with other boreholes, the drainage situation is poor. From May 24 to May 28, there were no data on the amount of pure gas drainage and the amount of mixed gas drainage, which may be due to the failure of the bottom of the hole caused by faults or hole collapse accidents in the process of propulsion, which caused too much impurity cinder in the borehole, blocked the gas circulation pipeline and affected the gas drainage effect. In the later period, hydraulic slag discharge was adopted in time to dredge the gas circulation pipeline.

As can be seen from Figure 5(b), on May 19th, the pure gas drainage volume and mixed gas drainage volume of No.2 borehole reached the maximum value during the drainage period, which were 5.52 m^3/min and 7.08 m^3/min respectively. In the whole process of gas drainage, the gas drainage concentration is stable at about 75%, and the maximum value can reach 80%. The good drainage effect is mainly due to the reasonable arrangement of No.2 borehole in the middle and lower part of the fracture zone, where the fracture is fully developed and has become a gathering area of a large amount of gas. The average concentration of gas extracted from 2# borehole is 72.23%, the average mixed amount of gas extracted is 4.38 m^3/min, and the average pure amount of gas extracted is 3.25 m^3/min.

As can be seen from Figure 5(c), the mixed gas extraction volume and pure gas extraction volume of 3# borehole first increase and then decrease, and the maximum value can reach 5.23 m^3/min and 3.56 m^3/min. During the whole process, the three curves will change slightly, but the overall trend tends to be stable, with an average gas extraction concentration of 68.75%, an average gas extraction mixed volume of 2.50 m^3/min and an average gas extraction.

Through the drainage situation of three boreholes, it can be seen that the gas drainage volume has a steady upward trend in the later period, mainly because with the advance of the working face, the cracks in the hole distribution range in the goaf continue to develop in the advancing direction until the cracks are connected, which provides a good space for the gas drainage flow channel and makes the gas drainage effect in the later period good. Generally speaking, in this range, long drilling holes are arranged to extract gas from the upper corner of goaf, and the effect of extracting gas concentration and flow rate by drilling holes is remarkable. It proves the rationality of the long borehole layout, and the feasibility of combining theoretical analysis with microseismic monitoring technology to investigate the range of fracture zone, which provides guidance for gas control in the upper corner in the future.

4.3.2 Analysis of gas drainage effect in goaf

The monitoring data of gas drainage in the process of mining in 3103 working face is summarized as shown in Figure 6. After the drainage, the average gas drainage concentration in the goaf is 53.55%, the average mixed amount of gas drainage is 9.12m/min, and the average pure amount of gas drainage is 5.37m/min.

In the production process of 3103 coal mining face, the actual air supply is 1320 m^3/min, and the absolute gas emission is 13.3 m^3/min. After the coal seam gas content is 2.99 m^3/min by pre-drainage with bedding drilling in the early stage of mining, there is still the risk of 9.37 m^3/min gas gushing to the working face, which leads to the gas accumulation area in the upper corner. After reasonably arranging the drilling field to control the gas in the goaf, the gas drainage amount is 5.37 m^3/min, which makes the gas concentration in the upper corner around 0.4% and the gas concentration in the return air roadway around 0.3%. It is proved that the use of long drilling holes in 3103 working face is beneficial to solve the problem of gas overrun and ensure the effect of gas drainage and control.

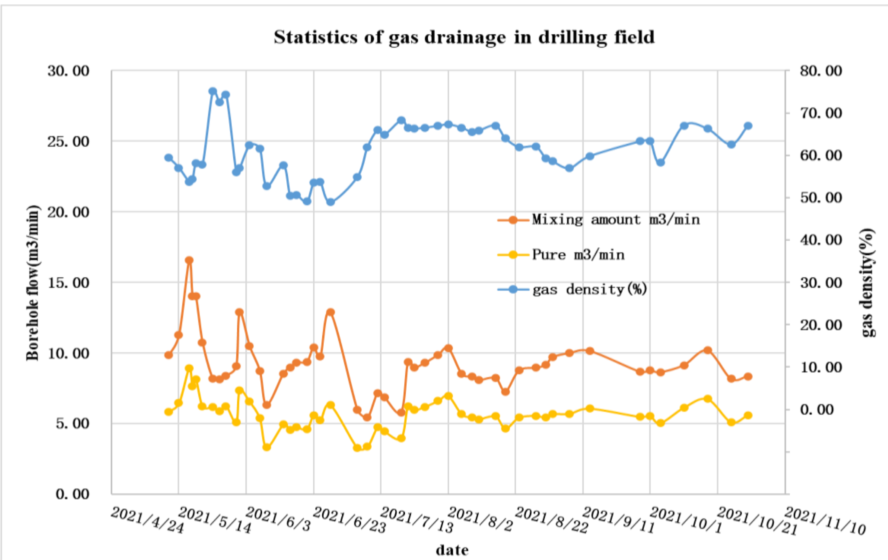


Fig 6.Summary of gas drainage data in drilling field

5. Conclusion

Combined with the actual conditions of 3103 south working face, microseismic monitoring technology is used to investigate the range of fracture zone in goaf of this working face, and long drilling holes are arranged in the range of fracture zone, and the drainage effect is verified, and the following conclusions are obtained:

(1) According to the actual situation of the working face, the working face sensor arrangement scheme and microseismic data collection scheme are formulated. The microseismic monitoring instrument is used to continuously monitor the microseismic events in the goaf of the working face, and the microseismic monitoring data are analyzed and calculated. It is concluded that the maximum height and the minimum height of the larger typical microseismic events are 34.2m and 6.8m, that is, the height of the fractured zone in the goaf ranges from 6.8 m to 34.2 m..

(2) By drilling a long hole 33m away from the normal of the roof, a large amount of gas in the goaf was extracted and treated. During the whole mining process, the average gas extraction concentration was 53.55%, and the average gas extraction purity was 5.37 m^3/min. After treatment, the gas concentration in the upper corner of the return air lane was about 0.4%, and the concentration in the return air lane was about 0.3%, which ensured the gas extraction control effect.

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