Study on gas drainage effect of hydraulic fracturing in soft coal seam

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Abstract. Aiming at the difficulty of gas drainage by drilling along the seam in soft coal seam, the permeability of coal seam was increased by hydraulic fracturing test in the field, and the permeability and gas drainage parameters of coal seam before and after fracturing were studied. The results show that: ① The fracture initiation pressure of 3# coal seam in Guojiahe coal mine is 15~20MPa. When the water injection is 30~40m^3, the fracturing radius is 15m, when the water injection is 50 ~ 60m^3, the fracturing radius can reach 20m, when the water injection reaches 70m^3, the fracturing radius can reach 30m; ② Driven by high pressure water, the gas in the fractured area migrates to the unfractured area, and the gas content in the fractured area decreases; ③ The attenuation coefficient of natural gas flow after fracturing is reduced by 50% compared with that before fracturing, and the permeability coefficient of coal seam after fracturing is increased by 50 times compared with that of original area; ④ The recovery concentration after fracturing is much higher than that before fracturing.

1 Preface

Coalbed methane (CBM) can effectively develop and utilize coal resources to reduce the hidden danger of major gas disasters in coal mines, turn greenhouse gases into treasure and increase the share of energy self-sufficiency.

Hydraulic fracturing of coal seam is a measure to make coal body fracture unblocked with water as power. The fracture of hydraulic fracturing creates good conditions for the flow of coal seam gas. After the high pressure hydraulic fracturing is applied to the gas bearing coal, the gas concentration and drainage volume of the drainage borehole can be greatly increased, which is one of the effective technical means to improve the gas drainage efficiency[1-2].

At present, domestic and foreign countries are vigorously studying and developing the technology and equipment related to CBM extraction and permeability enhancement. However, at present, the technology of permeability enhancement by hydraulic fracturing in coal mine is mainly limited to the through layer hole fracturing technology[3-4], and the research on the permeability increasing direction of drilling along the seam is still less[5]. Therefore, it is necessary to conduct permeability enhancement through field hydraulic fracturing test along coal seam to study the permeability of coal seam before and after fracturing And gas drainage parameters, Through hydraulic fracturing to increase the permeability of coal seam, the number of boreholes can be reduced, the gas control time of working face can be shortened. Hydraulic fracturing can make the stress in front of the working face become more uniform through the transmission of water pressure, thus reducing the risk of coal seam outburst caused by uneven distribution of stress.

2 Hydraulic fracturing test of drilling along seam in soft coal seam

2.1 Situation of 1307 working face in Guojiahe Coal Mine

The 1307 working face is located at +820m level in Guojiahe coal mine. The coal seam is 3# coal seam with an average thickness of 16m. The coal seam contains 1~2 layers of gangue, with a thickness of 0.2~0.5m. The dip angle of the coal seam is 7°, and the strike length of the working face is 2303m and the length of the working face is 235m. It is estimated that the original gas content of the coal seam in the working face is 3~4m^3/t. The 3# coal seam of the working face is black, and the coal petrology type is mainly semi dark type. The upper 3m and the lower 2m are semi bright briquette. The coal petrographic composition is mainly dark coal and bright coal, with local pyrite film, brown black stripes and uneven fracture. The upper and lower semi bright briquettes are layered structure, and the middle part is massive structure, strip structure and asphalt luster. The gangue is mudstone, and there is about 1 meter thick inferior coal in some areas.

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2.2. Design of hydraulic fracturing borehole

According to the geological conditions of coal seam and the actual production situation of 1307 working face, the test area is 230m working face from 120m away from the stoping line and heading inward. The fracturing radius of the bedding hole hydraulic fracturing test is designed according to the comparison of 15m and 20m. The bedding fracturing drilling hole is constructed in the return air gateway of 1307 working face. The designed borehole diameter of bedding hydraulic fracturing is 89mm and the hole depth is 180m. In the first group of fracturing tests, three fracturing boreholes (fracturing 1~ fracturing 3) were constructed in the air return channel of 1307 working face with a fracturing radius of 15m, in the second group, three fracturing boreholes (fracturing 4 ~ fracturing 6) were constructed in the air return channel of 1307 working face with a fracturing radius of 20m. In order to investigate the effectiveness of the fracturing design parameters in the fracturing process, the first group of fracturing tests constructed an auxiliary inspection hole 15m away from both sides of the hydraulic fracturing hole, and the second group of fracturing test constructed an auxiliary inspection hole at 20m from both sides of the hydraulic fracturing hole. The layout of fracturing boreholes and auxiliary boreholes is shown in figure 1. During the construction of all boreholes, the gas content, original water content and occurrence (whether there is gangue or soft stratification) in the coal seam shall be investigated. The auxiliary hole shall be connected to the drainage pipeline during the fracturing process, and the automatic waterproof and slag discharging device shall be set.

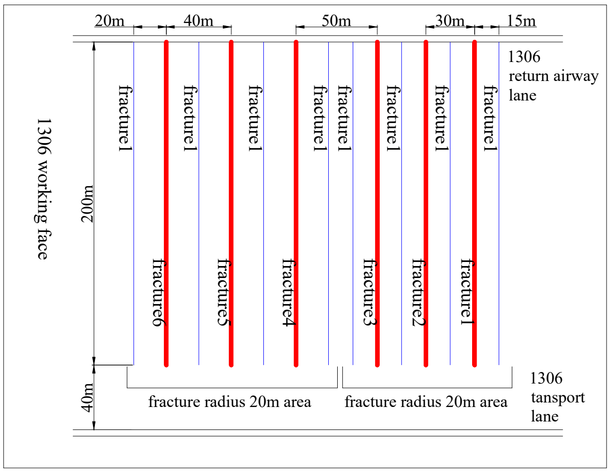

Fig. 1. Design of hydraulic fracturing borehole.

3 Sealing technology and fracturing parameters

3.1 Sealing technology

The underground hydraulic fracturing packer (MKY70 packer) is used to seal the fracturing borehole. Combined with the actual working conditions of the hydraulic pressure in the coal mine, the support and setting mode of the packer are improved. It has the characteristics of simple and reliable sealing, low cost and reusability. It is suitable for the fracturing of cross hole and bedding hole with any angle. The structure of MKY70 packer is mainly composed of upper and lower joints, intermediate pipe and rubber cylinder. During fracturing, the fracturing fluid passes through the fracturing pipe and enters the intermediate pipe of the packer from the upper joint. At this time, the fracturing fluid with certain pressure enters into the inner cavity of the rubber cylinder through the liquid inlet groove on the intermediate pipe, making the rubber cylinder swell and sealing the hole. After the fracturing fluid in the intermediate pipe is depressurized, the rubber cylinder is withdrawn and unsealed. The setting device is connected with the lower joint of the packer. Its function is to form a differential pressure in the packer when the fracturing fluid enters the packer, so as to ensure that the fracturing fluid can enter the annular cavity between the rubber cylinder and the intermediate pipe through the liquid inlet groove of the intermediate pipe of the packer. When the pressure inside the fracturing pipe reaches a certain degree, the setting device can open automatically, and the fracturing fluid flows into the screen pipe through the setting device, and then the fracturing starts. In order to achieve better sealing effect, double packers as shown in figure 2 are used.

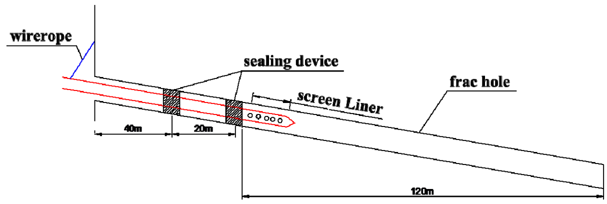

Fig. 2. Fracturing borehole sealing diagram.

3.2 Fracturing parameters

Through calculation[6], the fracture initiation pressure of coal seam is about 15MPa, and the pump injection pressure is about 20MPa. The water injection rate of each borehole is about 50~70m^3.

3.3 Fracturing water injection and hydraulic fracturing influence radius

In the process of water injection, there is black water flowing out from the auxiliary 7 and auxiliary 8 holes 20m away from the fracturing hole when the water injection is 50m^3. In the 6# fracturing hole, when the water injection is 70m^3, the water output of the extraction hole 30m away from the fracturing hole is larger. when the water injection volume of the 5# fracturing hole is 40m^3, a small amount of black water flows out of the auxiliary 6 and auxiliary 7 fracturing holes 20m away from the fracturing hole, and the water flow increases when the water injection volume reaches 60m^3, and when the water injection volume reaches 30m^3 in the 2# fracture hole, the water flow rate increases A small amount of water flowed out of the auxiliary 2 and auxiliary 3 holes 15m away from the fracturing hole, and the water volume increased when

the water injection was $50m^3$, when the water injection was $30m^3$ in the 1# fracturing hole, a small amount of black water flowed out from the auxiliary 1 and auxiliary 2 holes 15m away from the fracturing hole.
Finally the fracture initiation pressure of the coal seam in this working face is 15~20MPa. When water injection is $30\sim40m^3$, the fracture radius is 15m, when the water injection is $50\sim60m^3$, the fracture radius can reach 20m, and when the water injection reaches $70m^3$, the fracture radius can reach 30m.

4 Investigation of hydraulic fracturing effect

4.1 Investigation of coal seam gas content

The drilling parameters and gas content in the original area are shown in table 1, because of the driving effect of high-pressure water, the gas in the fractured area migrates to the unfractured area, and the gas content in the fractured area decreases.

Table 1. Comparison of gas content before and after fracturing

Location	Test time	Namber	Content (m^3/t)
Original area of 1307 return air duct	2019-10-9	34 extraction hole	3.68
fracturing area of 1307 return air gateway	2019-11-10	28 extraction hole	2.59

4.2 Attenuation coefficient and permeability coefficient of coal seam gas

The attenuation coefficient of borehole gas flow is one of the parameters to measure the difficulty of coal seam gas drainage. Through the measurement and calculation of borehole gas flow, it can be seen from table 2 that the attenuation coefficient of natural gas flow after fracturing is nearly 50% less than that before fracturing.

Table 2. Attenuation coefficient of coal seam gas flow

Before fracturing	After fracturing
$0.3725d^{-1}$	$0.1650d^{-1}$

The permeability of coal seam represents the difficulty of gas flow in coal seam and is an important index to measure the difficulty degree of gas pre drainage. It can be seen from the measurement results in table 3 that the permeability coefficient of coal seam after fracturing is nearly 50 times larger than that of the original area, and the fracturing effect is obvious.

Table 3. Coal seam permeability coefficient ($m^2/MPa^2.d^{-1}$)

Before fracturing	After fracturing
0.01227	0.6082

4.3 Attenuation coefficient and permeability coefficient of coal seam gas

After fracturing, the pumping boreholes are drilled in the fracturing area to investigate the fracturing effect. The layout of the drainage boreholes is shown in the following figure, the spacing of the designed pumping boreholes is 5m and 6.7m, and the schematic diagram of the layout of the drilling holes is shown in figure 3.

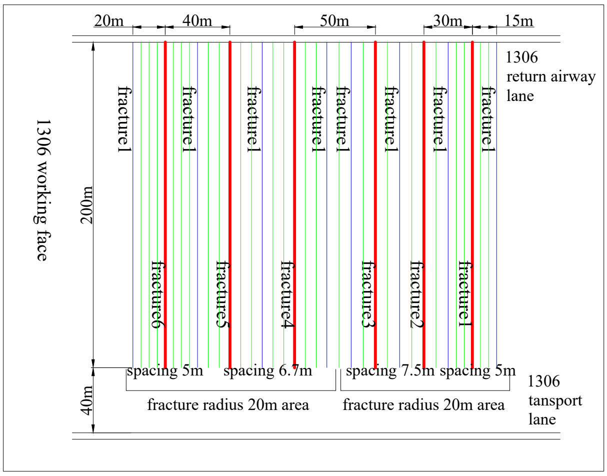

Fig. 3. Layout of boreholes for investigation of pumping radius after fracturing.

Before the drainage branch pipe enters into the main pipe connection, an orifice flowmeter is installed to inspect and measure the pumping volume and mixing volume. The recovery radius before and after fracturing was compared with the original recovery radius of 7m.

Figure 4 shows the comparison curves of the drilling drainage concentration in the original area, the area with the pumping radius of 5m after fracturing and the area with the pumping radius of 6.7m after fracturing. It can be seen from the figure that the pumping concentration after fracturing is significantly higher than that before fracturing, the average pumping concentration with a pumping radius of 5m after fracturing is increased by 10.1 times, and the average pumping concentration with a pumping radius of 6.7m is increased by 10.2 times.

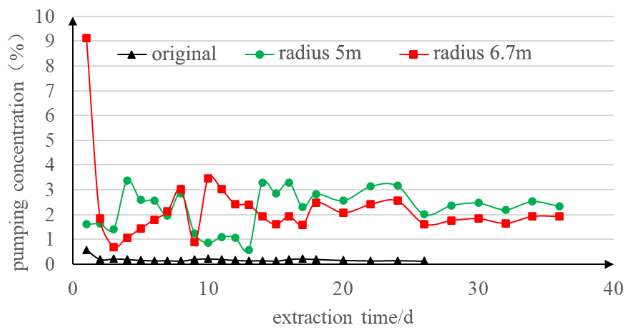

Fig. 4. Comparison curve of pumping concentration.

Figure 5 shows the comparison curves of pure gas drainage volume in the original area, the area with 5m drainage radius after fracturing and the area with 6.7m drainage radius after fracturing. It can be seen from the figure that, compared with the original area, the pure amount of gas drainage from the boreholes after fracturing has been greatly improved. The average single hole gas drainage net amount in the original area is $0.0019m^3$/min, and the average single hole gas drainage volume in the area with drainage radius of 5m after fracturing is $0.0126m^3$/min, which is 6.63 times higher than that of the original area; the average gas drainage pure quantity of the area with 6.7m drainage radius after fracturing is $0.0118m^3$ /min, which is 6.21 times higher than that of the original area.

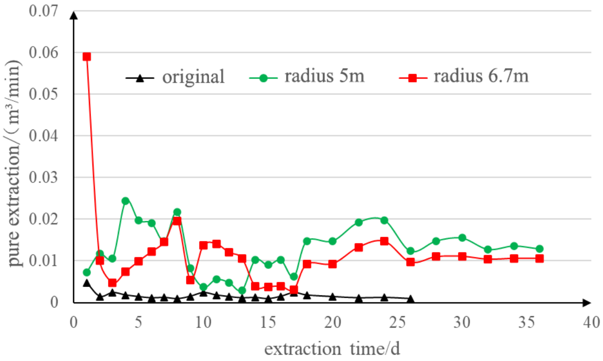

Fig. 5. Comparison curve of pure pumping volume

From the above analysis, it can be seen that: compared with the original area, the gas drainage concentration and the net amount of gas drainage after fracturing have been greatly improved. The average gas drainage oncentration and pure amount of single hole in the drainage area with drainage radius of 5m after fracturing and the drainage area with a drainage radius of 6.7m after fracturing are similar. Considering that the average thickness of coal seam in 1307 working face is 16m, which is an extra thick coal seam, in order to shorten the working face In order to ensure the safety of working face, the pre pumping scheme with extraction radius of 5m should be adopted.

5 Conclusion

(1) The fracture initiation pressure of the coal seam in this working face is 15~20MPa. When water injection is 30 ~ $40m^3$, the fracture radius is 15m, when the water injection is $50\sim60m^3$, the fracture radius can reach 20m, and when the water injection reaches $70m^3$, the fracture radius can reach 30m.

(2) Driven by high-pressure water, the gas in the fractured area migrates to the unfractured area, and the gas content in the fractured area decreases.

(3) The attenuation coefficient of natural gas flow after fracturing is reduced by 50% compared with that before fracturing, and the permeability coefficient of coal seam is increased by 50 times compared with the original area.

(4) After fracturing, the average concentration and purity of the extraction hole with a pumping radius of 5m are 10.1 times and 6.63 times higher than those of the original area, and the average pumping concentration and pure volume of the extraction hole with a pumping radius of 6.7m are 10.2 times and 6.21 times higher than those of the original.

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