Research on the influence of radius test based on hydraulic fracturing measures

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Abstract. By analyzing the mechanism of hydraulic fracturing, and the special geological conditions of a certain mine, the relevant parameters of hydraulic fracturing and increasing permeability suitable for the mine are determined through on-site fracturing pump tests. After two sets of hydraulic fracturing tests in the test areas, and compared with the original drainage parameters, the average coal seam gas drainage concentration increased by an average of 3.55, 3.65 times, and the scalar drainage increased by 3.6, 3.1 times. The average water content of coal seams increased by 1.43 times and 1.65 times. Finally, after comprehensive analysis of the borehole gas drainage concentration, gas drainage scalar and coal seam water content measured in test area 1 and test area 2, it is concluded that the influence radius of fracturing and permeability is 25~30m. It provides an effective reference for the layout of hydraulic fracturing boreholes and increasing the effect of gas drainage.

1. Introduction
The emergence of coal and gas outbursts is one of the main restrictive factors that affect coal mine safety production. At present, the main method for preventing and controlling coal and gas outbursts is to extract gas in advance through construction boreholes. However, due to the characteristics of low air permeability of the soft coal seam, the density of construction drainage holes is high, and takes long time for construction, which seriously affects the effect of gas drainage.

By Underground hydraulic fracturing technology to increase the permeability of coal seams has become one of the effective measures to control gas disasters in mines. The mechanism of hydraulic fracturing to increase air permeability is to use high-pressure liquid to inject the coal seam. As the liquid pressure increases, it overcomes the tensile strength of the coal and rock mass, and causes the weak surface of the coal to develop tensile cracks. The expansion of a large number of weak surface cracks in the coal body not only increases the porosity of the coal seam, but also gradually penetrates to form a fracture network with the expansion of the fractures. After the fracturing measures are completed, the flow of liquid will form a good fracture network channel for gas migration. Therefore, the goal of improving the effect of gas drainage is achieved. However, due to the different geological conditions of the mines in different mining areas and the lack of relevant theories, after air permeability increased via hydraulic fracturing measures, it is difficult to accurately obtain the range...
of increased air permeability by fracturing, resulting in unreasonable gas drainage drilling arrangements. The final effect of gas extraction is not ideal [1-3]. Therefore, the mine adopts hydraulic fracturing technology and equipment to increase air permeability, and uses the method of field test to increase the air permeability of fracturing and determine the influence radius of fracturing construction parameters. It provides theoretical guidance for increasing the effect of gas drainage.

2. Hydraulic fracturing enhancement test

2.1. Overview of the test site
The thickness of the coal seam at the test site is 0.20～4.96m, the average thickness is 1.54m, the recoverable thickness is 0.80～4.96m, and the average thickness is 1.57m. The roof is thick black mudstone with thin gray-black siltstone and fine sandstone strips on top, The floor is black-gray fine sandstone, the solidity coefficient of the coal body is 0.3, and its water content is 0.92%, The coal mass near the roadway has low gas drainage efficiency and low coal permeability, which is a typical soft and low-permeability coal seam.

2.2. Fracture drilling layout
In order to improve the accuracy of investigating the influence radius of hydraulic fracturing, the technical route of this paper is to comprehensively judge the influence radius of hydraulic fracturing through the measurement of gas drainage concentration, coal seam water content and pure gas drainage flow. Two test areas are arranged, namely test area 1 and test area 2. In test area 1, 1 fracturing hole is arranged, and 1 test hole and 6 observation holes are arranged on the left side of the fracturing hole; In test area 2, 1 fracturing hole is arranged, and 1 test hole and 6 observation holes are arranged on the right side of the fracturing hole. The fracturing boreholes are respectively arranged at 220m and 430m away from the stop line, with a hole diameter of 94mm and a hole depth of 70m. Before fracturing, one test hole was constructed 40m away from one side of the fracturing borehole in the two test areas. After the fracturing process, the gas observation borehole was constructed, and the borehole spacing was 5m intervals. The hole diameter is 96 mm, and the hole depth is 110m. as shown in picture 1.

![Drilling layout plan of test area.](image)

2.3. Determination of fracturing parameters
For hydraulic fracturing, the most important determinant of the effect of hydraulic fracturing is the determination of water injection pressure and flow rate [4-6].

2.3.1. Pump injection pressure. Pump injection pressure Pw can be expressed as

\[ P_w = P_k - P_H + P_r + P_f \] (1)
Pk — Coal seam fracture pressure;  
PH — Injection pressure of fracturing pipeline;  
Pr — Friction resistance of fracturing fluid along the pipeline;  
Pf — Friction resistance of fracturing fluid at the end of the pipeline.

The rated pressure of the fracturing pump should be greater than the pump injection pressure Pw. Combining the previous fracturing experience and the specific coal and rock mass and geological conditions of the fracturing area, the pressure of the fracturing pump unit is designed to be about 30MPa.

2.3.2. Fracturing fluid consumption. The amount of fracturing water injection is mainly related to the fracturing radius, fracturing aperture, coal thickness and porosity, the amount of fluid used for fracturing is calculated according to the following formula:

\[ V = \pi (R - r)^2 H \phi \]  

R — Estimated fracture radius, m;  
r — Hole radius, m;  
H — Coal seam thickness, m;  
\( \phi \) — Porosity, %.

According to calculations, the water injection volume of each borehole for hydraulic fracturing and anti-permeability measures is about 60~70m3.

3. Hydraulic fracturing enhancement test

Before hydraulic fracturing, the fracturing pump needs to be debugged. First, the system starts to operate for 15 minutes, and after checking whether the fracturing system is normal, start hydraulic fracturing. According to Figure 2, when the pump pressure is close to 20MPa, the pressure in the water pipe is also less than 20MPa; When the pump pressure increases to 30.5MPa, the pressure value of the fracturing pipeline drops rapidly after reaching the peak value. After the hydraulic fracturing time is 280min, the water injection pressure is maintained at about 24MPa, and then the hydraulic fracturing test is stopped [7-8].

![Figure 2. Variation curve of fracturing pressure and flow with time.](image)

The maximum water injection pressure of this fracturing is 30.5MPa, and the total time lasts for 5.8h. It can be seen that the actual water injection pressure is slightly higher than the calculated pressure value because of the frictional resistance of the pipeline and the heterogeneity of the coal seam.

4. Determination of the radius of influence of hydraulic fracturing

4.1. The law of gas drainage concentration and flow rate

After the fracturing process is completed, drainage boreholes will be constructed in the test area 1 and the test area 2, and the water content of the coal seam will be measured at the same time, and the
network drainage will be carried out. The comparison of single-hole gas drainage concentration and drainage scalar within 30 days of test holes in the two test areas before fracturing and six observation holes after fracturing are shown in Figure 3~6.

**Figure 3.** Change curve of gas drainage concentration in test hole and observation hole in test area 1 with time.

**Figure 4.** Time curve of pure gas drainage flow in test hole and observation hole in test area 1.
It can be seen from Figures 3-6 that the observation holes 1-1~1-4 and 2-1~2-4 in the test area 1 and the test area 2 are compared with the test holes in the respective test areas. The gas drainage concentration and pure drainage flow are shown in Table 1.
Table 1. Comparison of test holes in the test area.

| Pilot projects | Hole number | concentration(%) | Scalar(m3/min) | Remarks |
|----------------|-------------|------------------|---------------|---------|
| Before fracturing | Test hole 1 | 15 | 0.014 |          |
|                  | Test hole 2 | 12 | 0.01 |          |
|                  | Observation hole 1-1 | 59 | 0.056 |          |
|                  | Observation hole 1-2 | 55 | 0.05 |          |
|                  | Observation hole 1-3 | 48 | 0.047 |          |
|                  | Observation hole 1-4 | 44 | 0.043 |          |
|                  | Observation hole 2-1 | 65 | 0.04 |          |
|                  | Observation hole 2-2 | 55 | 0.055 |          |
|                  | Observation hole 2-3 | 48 | 0.038 |          |
|                  | Observation hole 2-4 | 43 | 0.032 |          |
| After fracturing |                         |      |          |         |

Comparing and analyzing the changes of gas drainage concentration and pure flow in the test area, test area 1 increased by 3.2 to 3.9 times and 3.3 to 4 times; test area 2 increased by 12.9 to 4.3 times and 2.3 to 3.9 times. On the 30th day of observation, the observation hole drainage concentration was basically maintained at the initial level of the test hole, and the average gas drainage concentration and pure flow rate of observation holes 1-5 and 2-5 were slightly higher than those of the test hole. The gas drainage concentration and pure flow of observation holes 1-6 and 2-6 are basically the same as those of the test holes. The above situation shows that the test area 1 and the test area 2 hydraulic fracturing increases the gas permeability. The fracturing effect only affects between 1-5 to 1-6 bores and between 2-5 to 2-6 holes. The final distance does not exceed 30m.

4.2. Change regularity of water moisture content

Comparison of coal samples of 1-1 to 1-6 and 2-1 to 2-6 in the test region 1 and 2-1 to 2-6 in the test area, 1, 2, is shown in Table 2. The original water content of the coal seam is 1.23% [9-10].

Table 2. Distribution of moisture content of each observation hole after fracturing.

| Hole | Water content % | Multiple | Hole | Water content % | Multiple |
|------|----------------|----------|------|----------------|----------|
| 1-1  | 2.94           | 2.39     | 2-1  | 2.89           | 2.35     |
| 1-2  | 2.23           | 1.81     | 2-2  | 2.34           | 1.9      |
| 1-3  | 2.11           | 1.72     | 2-3  | 2.06           | 1.67     |
| 1-4  | 1.79           | 1.46     | 2-4  | 1.84           | 1.5      |
| 1-5  | 1.75           | 1.42     | 2-5  | 1.72           | 1.4      |
| 1-6  | 1.44           | 1.17     | 2-6  | 1.32           | 1.07     |

It can be seen from Table 2 that the closer the observed hole is, the higher the water content of the coal body, and the less. 1-6 observation holes and 2-6 observation holes farthest, and the coal moisture content is the least. Almost close to the original media moisture rate is close to the fracturing hole 30m distance. Therefore, it is understood that the above analysis is found that the hydraulic pressure fraction is reduced by 25 to 30 m.
5. Conclusions
Due to the influence of pipeline friction resistance, the hydraulic pressure of the coal seam is actually 30.5MPa, which is slightly larger than the theoretical value of 30 MPa, which can provide theoretical guidance for a mineral hydraulic pressure.

After using hydraulic fracturing penetration measures, it is known that the drilled gas mining concentration and pure flow in the test region 1 and the test area 2 can be seen, and the value has a significant increase, the drilling water content is significantly increased. After comprehensive analysis, hydraulic fracturing has an increase in radius from 25 to 30m, providing an effective reference for a mineral pressure fracturing drilling arrangement and increasing gas extract effect.

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