Application research on hydraulic fracturing of cross-layer drilling in Sijiazhuang Coal Mine

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Abstract. The No.15 coal seam of Sijiazhuang Coal Mine belongs to high gas and low permeability coal seam. Hydraulic fracturing, as a technical measure for outburst prevention, is more and more widely used in high gas outburst mines. The influence of hydraulic fracturing high-pressure water on stress and displacement of roadway is analyzed, and the feasibility of hydraulic fracturing is verified. The industrial test of hydraulic fracturing through layers was carried out and the effect of gas extraction was investigated. The average concentration and pure volume of gas extraction unit in the fracturing area were 3.1 times and 5.7 times of those in the non fracturing area, respectively, which verified the permeability increasing effect of hydraulic fracturing measures. Through fracturing test, the extraction effect has been significantly improved. This paper provides important theoretical support and practical basis for hydraulic fracturing under similar conditions.

1. Introduction

It is difficult to control the gas in the coal seam with high gas, broken soft and low permeability [1-2]. How to improve the permeability of coal seam is an important research topic in China's scientific research institutes, universities and coal enterprises [3-6]. At present, a series of coal seam gas enhanced drainage technologies have been formed, including deep hole presplitting blasting, hydraulic punching, hydraulic cutting, hydraulic fracturing and so on [7-9]. In order to reduce the time of gas extraction and ensure the safe and efficient production of coal mine, domestic and foreign scholars have made a breakthrough in technology [10]. On the basis of previous studies, the author thinks that it is of great significance to carry out the hydraulic fracturing application after the analysis of the hydraulic fracturing compressibility of through layer drilling in different coal mines.

In this paper, numerical simulation is used to analyze the influence of in-situ stress change caused by high-pressure water injection on the stress and displacement of floor rock pre pumping roadway, so as to ensure the safety of fracturing construction in the test area. The high gas content and poor permeability of 15 coal seam in Sijiazhuang mine of Yangquan Coal Group lead to a series of problems, such as difficult extraction and tight production replacement. Taking the mine as an example, the author analyzes the compressibility of the bottom drainage roadway through the layer drilling. The effect of hydraulic fracturing in the test area is investigated, and a complete set of technical system suitable for
hydraulic fracturing of through layer drilling is formed, which provides theoretical support and practical basis for hydraulic fracturing of through layer drilling.

2. Analysis of hydraulic fracturing compressibility of through hole
The fracturing test area is in the return air bottom pumping roadway of 15117 working face in Sijiazhuang mine. The delineated fracturing test area has undeveloped geological structure and poor permeability. There is no permeable geological structure within the scope of fracturing test. The roof and floor of coal seam are not easy to expand when encountering water, and there is no aquifer in the roof and floor. This area theoretically meets the requirements of hydraulic fracturing test.

2.1. Establishment of calculation model
Hydraulic fracturing may cause roof separation, collapse and spalling of bottom drainage roadway. In order to prevent these situations, according to the data of Sijiazhuang mine fracturing test area, the author simulated the stress and displacement changes before and after the implementation of hydraulic fracturing under the support conditions. Through the comparison before and after, the influence of hydraulic fracturing high-pressure water on the experimental roadway is obtained. The layout of fracturing boreholes is as shown in Figure 1. In this simulation, 2 # fracturing boreholes are selected, with the planned water injection of 90m³ and the maximum water injection fracturing pressure of 20MPa.

![Figure 1. 2# fracturing borehole layout profile](image)

According to the drilling data, a numerical simulation model with the size of 150m × 100m × 80m is established, as shown in Figure 2. The boundary conditions of the model are as follows: the vertical load is applied in the vertical direction to simulate the self weight of the overlying strata, the horizontal movement is limited in the X and Y directions, and the vertical displacement of the bottom is limited in the Z direction. The molding depth is 300m and the bulk density is 25KN/m³, so the stress value of 7.5Mpa is applied on the upper boundary of the model. The parameters of surrounding rock of the model are shown in Table 1.

![Figure 2. Numerical simulation model of bottom extraction roadway](image)
Table 1. Coal and rock parameters in calculation model

| Rock character       | Density $\text{kg/m}^3$ | Bulk modulus $10^9\text{Pa}$ | Cohesion $10^3\text{Pa}$ | Internal friction angle $(^\circ)$ |
|----------------------|--------------------------|-------------------------------|--------------------------|-----------------------------------|
| Sandstone            | 2400                     | 0.85                          | 0.18                     | 31                                |
| Gangue inclusion     | 2000                     | 1.31                          | 0.70                     | 33                                |
| Overlying strata     | 2700                     | 1.94                          | 1.28                     | 35                                |
| Fine Sandstone       | 2700                     | 2.00                          | 1.70                     | 38                                |
| No.15 coal seam      | 1400                     | 0.16                          | 0.52                     | 27                                |
| Tunnel               | 2700                     | 1.94                          | 1.28                     | 35                                |
| Floor rock           | 2700                     | 2.30                          | 1.70                     | 38                                |

2.2. Comparison of stress changes in roadway before and after hydraulic fracturing

Firstly, the stress state of the roadway before hydraulic fracturing is simulated. Because the fracturing design is upward fracturing hole, the vertical stress change of roadway is mainly analyzed. Figure 3 shows the vertical stress nephogram of the test roadway before the implementation of hydraulic fracturing. It can be seen from the figure that the maximum vertical stress is 11mpa, and the stress distribution on the left and right sides is uniform.

![Figure 3. Vertical stress nephogram of roadway before hydraulic fracturing](image)

The maximum water injection pressure is 20MPa, and the superposition of high-pressure water pressure and original rock stress is equivalent to applying the maximum vertical stress of 30MPa in the center of the borehole. The influence of high-pressure water stress on the stress around the borehole is simulated, and the stress value gradually decreases to 10MPa in the range of 35m. The simulation results are shown in Figure 4.

![Figure 4. Vertical stress nephogram in plane direction of coal seam after hydraulic fracturing](image)
Figure 5 shows the vertical stress nephogram of roadway surrounding rock in the test area after hydraulic fracturing. Under the action of high pressure water, the maximum vertical stress of the left side of the roadway increases to 16MPa, which is 5MPa higher than that before fracturing. The maximum stress on the right side is 13 MPa, which is 2 MPa higher than that before fracturing. The stress distribution is no longer uniform.

2.3. Comparison of lane strain changes before and after hydraulic fracturing

Figure 6 shows the cloud diagram of vertical displacement under the condition of roadway support. It can be seen from the figure that the displacement of roof and floor is small, the displacement of roof is 1cm, the displacement of floor is 2cm, and the roadway is in a stable state.

Figure 7 shows the vertical displacement nephogram of the roadway after hydraulic fracturing. It can be seen from the figure that after hydraulic fracturing, the displacement value of the roof is 5cm, increased by 4cm, and the displacement value of the floor is 2cm, which remains unchanged. However, due to the stable lithology of the surrounding rock of the roadway and the support in place, the roadway is still in a stable state. It can be seen that hydraulic fracturing has little impact on the pressure test roadway.
3. Investigation on hydraulic fracturing effect of through hole drilling
As shown in Figure 8, after fracturing, the gas drainage concentration of fracturing unit is 13.9-36.5%, with an average concentration of 29.1%. While the gas drainage concentration of non fracturing area is 5.9-11.8%, with an average concentration of 9.3%, with an average gas drainage concentration of 3.1 times that of non fracturing area.

The results show that the average gas drainage pure quantity in fractured area is 0.97-3.44L/min, and the average gas drainage pure quantity is 2.04L/min, while that in non fractured area is 0.19-0.52L/min, and the average gas drainage pure quantity is 0.36L/min. The average gas drainage pure quantity after fracturing is 5.7 times of that in non fractured area, as shown in Figure 9, which significantly improves the gas drainage efficiency.

Figure 8. Contrast Chart of Gas Drainage Concentration Change between Fractured and Unfractured Areas

Figure 9. Contrast Chart of Gas Drainage Purity Change between Fractured and Unfractured Areas
4. Conclusion
(1) Through the numerical simulation analysis of the compressibility of the floor roadway in Sijiazhuang coal mine, it is concluded that the stress value of the roadway changes after fracturing, the stress value of the left and right sides is no longer uniform, and the stress of the fractured side is larger; the deformation of the roadway changes less after fracturing, which shows that the hydraulic fracturing has little effect on the bottom roadway in the test area, and can meet the requirements of hydraulic fracturing construction.
(2) The average concentration and purity of gas drainage unit in the fractured area are 3.1 times and 5.7 times of those in the non-fractured area, respectively.

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