Research on Influence Rules of Gas Content and Water Content in Low Permeability Coal Seam after Repeated Hydraulic Fracturing

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Abstract: Aiming at the problems of low permeability and poor extraction effect of coal seam in China, hydraulic fracturing repeatedly and effect investigation tests are carried out in low permeability coal seam of No.12 Mine of Pingdingshan Coal Mining Group Corporation. The variation rules of gas content and water content in coal seam(Ji15) are analyzed in detail. The results show that the effect of repeated fracturing on gas content and water content in low permeability coal seam is obvious. The average gas content of coal seam(Ji15) is 63% lower than one of original coal seam within effective range(35m) around fracturing hole, and the average water content of coal seam(Ji15) is 3 times higher than one of original coal seam. By and large, the gas content decreases gradually from fracturing hole to surrounding area, and water content is higher or lower generally in local area. The research results can provide reference for optimization of hydraulic fracturing parameters and extraction holes in low permeability coal seam.

1. Introduction

With the continuous increase of mining depth in China, the situation of low permeability, high gas, high ground temperature and high ground stress faced by most coal seams of mines are becoming more and more serious, which will affect seriously the extraction of gas and the safe and efficient production in mines, among which permeability of coal seam is the critical factor[1-2]. At present, the main means of enhancing permeability of low permeability coal seams are hydraulic punching, hydraulic cutting and pre-splitting blasting of deep hole, etc. However, due to the problems of small effective impact range, large workload, complex technology and low extraction rate, they are difficult to get a large scale, safe and efficient application in China[3]. In recent years, as the main measure increasing production of oil and gas, hydraulic fracturing technology has begun to be applied to rock gate uncovering, strip driving and other projects in coal mines, and has also achieved certain results[4-5]. But there are many shortcomings in basic theory, equipment level and process parameters. There is no complete set of hydraulic fracturing theory and technology system in coal mine based on the characteristics of gas occurrence, tectonic fissure site and stress field[6].

Therefore, many scholars have carried out underground hydraulic fracturing tests in low permeability coal seam, but more emphasis are laid on fracturing theory, permeability enhancement effect and other aspects. There are few reports on the impact of repeated hydraulic fracturing on gas content and water content in low permeability coal seam. Therefore, repeated hydraulic fracturing test is carried out in low permeability coal seam of No.12 Mine of Pingdingshan Coal Mining Group Corporation, and the variation rules of gas content and water content in coal seam(Ji15) after repeated fracturing are analyzed, which provide reference for optimization of hydraulic fracturing parameters and extraction holes in low permeability coal seam.

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2. Gas migration mechanism in hydraulic fracturing

Hydraulic fracturing technology is powered by incompressible high-pressure water, overcoming the natural leakage and surrounding rock stress of the target coal seam, injecting a large amount of high-pressure water into the target coal seam, and forcing the target coal seam under the action of its "water wedge" to connect the primary cracks and initiate-expand-extend new cracks, so that the coal seam is filled with fracture voids centered on fractured holes. In the meantime, the transport channel of gas is formed, so as to increase the permeability of coal seam[7-9].

During hydraulic fracturing, the flow of high-pressure water in coal seam is easy first and then difficult in sequence. First, it enters the secondary fracture circle by construction fracture hole. Secondly, it connects the primary fracture to the secondary fracture, and finally entering the micro-fracture network. When fracturing water enters the micro-fracture network, it will permeate to both sides of the fracture and contact with the free gas in the pore, resulting in water pressure greater than the gas pressure. The pressure gradient will make the free gas flow from high pressure area to low pressure area. At this time, the part of water will replace the free gas leaving. The whole process is called displacement effect. Therefore, the whole fracturing process will lead to gas redistribution within the effective influence range of fracturing hole.

However, repeated fracturing will generate new stress in the direction of vertical and parallel fractures, continuing to flush and expand the formed or closed fractures, and on this basis, re-initiate, expand and extend new fractures, which will widen further and develop the formed micro-fracture network, and gas also redistributed within the effective influence range of fracturing holes under displacement effect. If there are some weak surfaces in the coal seam, a large amount of high-pressure water existed will be accumulated again.

3. Basic situation of tested area

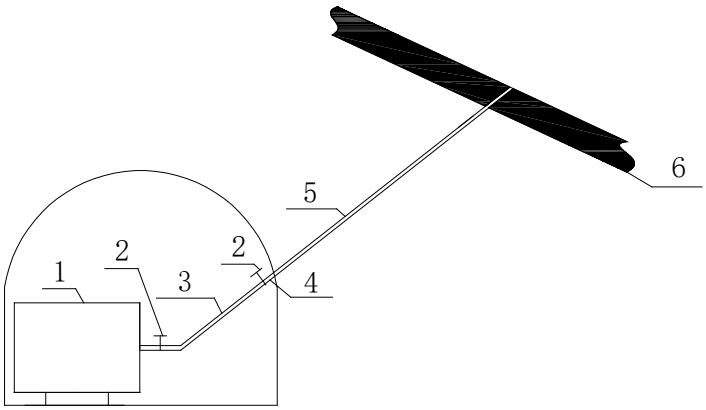
It is located in the eastern part of Pingdingshan coalfield that No.12 Mine of Pingdingshan Coal Mining Group Corporation. The approved coal seams in the minefield are Ji-group and Geng-group, The main coal seams (Ji15 and Ji16-17) are outburst coal seams. They are high gas content, high gas pressure, low permeability and extraction difficultly, which result in difficulties of roadway excavation, large amount of drilling work and tight production in mines.

The tested area is the strip of coal roadway in working face (Ji15-31040), and the construction site is the bottom drainage roadway (Ji15-31040). The average coal thickness of the target coal seam(Ji15) is 3.3m, the average dip is 10 degrees, the buried depth is from 828m to 877m, the original average gas content is 8.67m^3/t, the water content is 1.26%, and the permeability coefficient is 0.0218m^2/(MPa^2.d). The overall occurrence of coal seam in working face is good, the roof is sandy mudstone and sandstone, the floor is sandy mudstone, and the geological structure is simple.

4. The technology of hydraulic fracturing test repeatedly

In the bottom drainage roadway (Ji15-31040), there are six upward fracturing holes with a distance of 50 m. The sealing technology of "two blockages and one injection" is adopted. Under the premise of using the sealing material "cement (425#) + expansive agent (U)", the whole rock section of the fracturing hole is sealed up to the bottom plate of coal seam (Ji15). The schematic diagram of the relationship between hydraulic fracturing hole and coal seam location is shown in Fig.1.

This fracturing test uses underground fracturing pump(BYW450/70) produced by China Coal Technology and Engineering Group Chongqing Research Institute, as well as high-pressure rubber hose with bearing pressure(70MPa). According to the geological conditions of the test area, this fracturing test uses repeated water injection mode. High-pressure hydraulic fracturing can be carried out after 48 hours of cement solidification and after evacuation of all staff members within 200m around the fracturing hole and downwind side of the fracturing working roadway.



1.Fracturing pump 2.Cutoff valves 3.High-pressure hose 4.Seamless steel tube
5.Hydraulic fracture bore 6.Coal seam (ji15)

Fig.1 The schematic diagram of relationship between hydraulic fractures bore and seam location

The repeated fracturing process: 1) After the evacuation of unrelated personnel and the preparation of the warning personnel, it starts 5MPa pressure test after connecting pipeline. The debugging work can be completed when the whole pipeline is not abnormal. 2) The first fracturing is started until amount of the required water reached, and then the pressure is maintained, and when the pressure is reduced to 5MPa, the first fracturing work is completed. 3) The second fracturing is carried out as the first fracturing process, and the total amount of water injection repeatedly in a single hole is completed. The process parameters of fracturing hole (1#) in this test are shown in Table 1.

Table 1 The process parameters of fracturing hole (1#)

Drill number	Injection times/h	Injection frequency	Pressure/MPa		Injection rate/m^3	
			Stable injection	Initial pressure keeping	Single injection	Cumulative injection
1#	1.1	1nd	26	20	8	110
	1.5	2nd	27	25	13	
	2.7	3nd	28	20	27	
	3.1	4nd	26	22	30	
	3.3	5nd	22	23	32	

5. Effect investigation of repeated fracturing test

Taking fracturing whole (1#) as the center, nine investigation holes are designed along the trend of coal seam with spacing (5m), and nine investigation holes were designed along the inclination of coal seam with spacing (8m). The layout of investigation holes are shown in Fig.2.

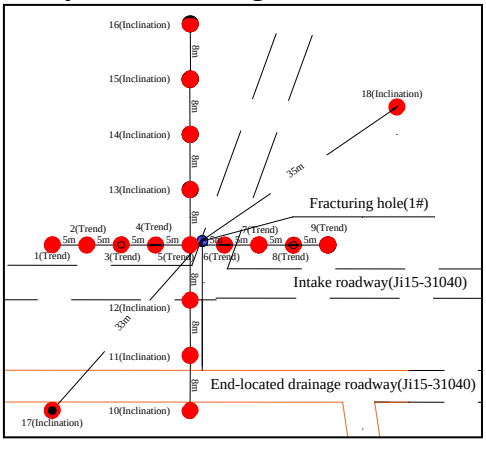


Fig.2 The layout plane of drilling holes for effect investigation after repeated fracturing

The gas content and water content of the coal sampling (Ji15) from investigation holes are measured in the laboratory after the pressure retention completed and some high-pressure water discharged in reverse. The measured data are shown in Table 2.

Table 2 The gas content and water content in coal seam (Ji15) after fracturing repeatedly

Inspection hole number	Distance from 1# fracture hole/m	Gas content/ $m^3.t^{-1}$		Water content/%	
		Before fracturing	After fracturing	Before fracturing	After fracturing
1(Trend)	22	8.67	1.79	1.26	2.95
2(Trend)	17	8.67	1.66	1.26	1.93
3(Trend)	12	8.67	3.38	1.26	2.01
4(Trend)	7	8.67	3.34	1.26	2.14
5(Trend)	2	8.67	3.88	1.26	2.63
6(Trend)	3	8.67	7.36	1.26	3.27
7(Trend)	8	8.67	3.72	1.26	4.92
8(Trend)	13	8.67	4.65	1.26	8.74
9(Trend)	18	8.67	2.88	1.26	6.7
1(Inclination)	24	8.67	2.44	1.26	5.79
2(Inclination)	16	8.67	2.76	1.26	2.36
3(Inclination)	8	8.67	3.36	1.26	2.75
4(Inclination)	8	8.67	2.44	1.26	2.8
5(Inclination)	16	8.67	2.45	1.26	2.89
6(Inclination)	24	8.67	2.31	1.26	2.59
7(Inclination)	32	8.67	2.34	1.26	2.67
8(Inclination)	33	8.67	4.37	1.26	-
9(Inclination)	35	8.67	2.27	1.26	5.78

According to the data in Table 2, the average gas content of coal seam in the 35m area around fracturing hole(1#) after repeated fracturing is 3.19m^3/t, which is 63% lower than 8.67m^3/t of the original content, and the average water content is 3.70m^3/t, which is about 3 times higher than 1.26% of the original water content.

5.1 The change rule of gas content

According to the data in Table 2, the change rule of gas content in coal seam (Ji15) after repeated fracturing is investigated, taking fracturing hole (1#) as the center, along the inner section of the coal seam and the upper part of the roadway as the negative half-axis, along the outer side of the coal seam and the downside side of the roadway as the positive half-axis, as shown in Fig.3.

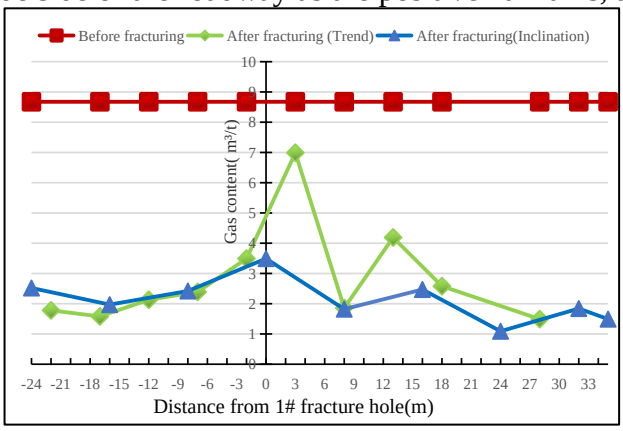


Fig.3 The comparison chart of gas content in coal seam before and after fracturing repeatedly

From Fig.3, it can be seen that the decrease of average gas content along the inclination of coal

seam (Ji15) is higher than one of the trend after repeated fracturing, the decrease of average gas content of the inner section along trend of coal seam is higher than one of the outer section, and the decrease of average gas content of the lower side of roadway is higher than one of the upper side. By and large, the gas content after repeated fracturing decreases gradually from fracturing hole (1#) to surrounding area. This is because repeated fracturing makes the micro-fracture network centered on the fracturing hole to be broadened, strengthened and developed fully, then the gas desorbed and free gas accumulated in the micro-fracture network after part of high pressure water discharged back.

5.2 The change rule of water content

With the same gas content, the change rule of water content in coal seam (Ji15) after repeated fracturing is investigated, as shown in Fig.4.

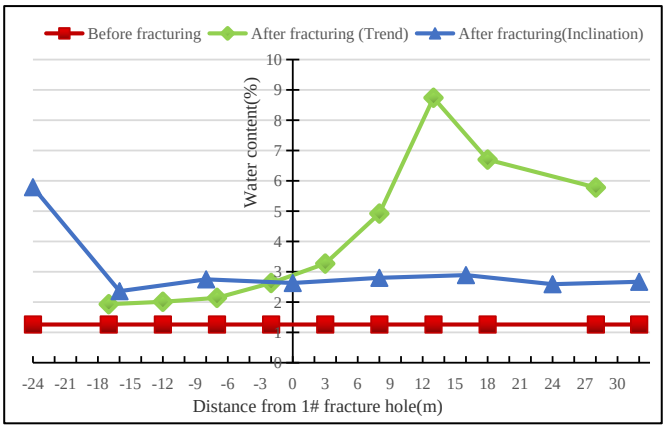


Fig.4 The comparison chart of water content in coal seam before and after fracturing repeatedly

From Fig.4, it can be seen that the increase of average water content along the trend of coal seam(Ji15) after repeated fracturing is higher than one of the inclination. The increase of average water content of the outer section along trend of coal seam is higher than one of the inner section. The increase of average water content of the upper side of roadway is higher than one of the lower side. The water content along trend and tendency of the coal seam is generally higher or lower in local area, and the difference also is large. This is because repeated fracturing is easy to cause repeated accumulation of local water in coal seam, resulting in higher for water content of coal seam.

6. Conclusion

(1) The repeated water injection mode in this hydraulic fracturing test is adopted. The fracturing process parameters repeatedly (5 times) are 22-28MPa of stable water injection pressure, 20-25MPa of initial pressure and 110m^3 of cumulative water injection.

(2) The effect of repeated fracturing on gas content and water content in low permeability coal seam is obvious. The average gas content of coal seam(Ji15) is 63% lower than that of original coal seam within effective range(35m) around fracturing hole, and the average water content of coal seam(Ji15) is 3 times higher than that of original coal seam.

(3) by and large, the gas content after repeated fracturing decreases gradually from fracturing hole to surrounding area , and water content is generally higher or lower in local area. The research results can provide reference for optimization of extraction holes in low permeability coal seam.

Acknowledgments

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