ISSN: 2414-1895 DOI: 10.6919/ICJE.202308_9(8).0028

Study on Gas Drainage Technology of Coal Mine Roof Strike Long Borehole Subsection Hydraulic Fracturing

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Abstract

Fracking technology is an effective means to increase the permeability of coal seams and effectively extract gas. On the basis of analyzing the advantages of directional drilling technology and Fracking technology, the anti-reflection technology of segmental fracturing of branch holes in the roof of directional drilling machine was studied. From two aspects of technical transformation and equipment optimization, a set of segmental hydraulic fracturing technology system of roof strike long borehole suitable for soft and low permeability coal seam was formed and applied. The research results show that the technical system operates stably and reliably, greatly improves the gas extraction effect of coal seam, increases the average single-hole gas extraction flow by more than 2 times, increases the extraction concentration by more than 30%, and significantly improves the extraction effect, which verifies the superiority of segmenting hydraulic fracturing in the direction of roof drilling.

Keywords

Coal Mine; Gas Drainage; Subsection Hydraulic Fracturing; Long Borehole.

1. Introduction

Coal seam gas extraction is one of the most effective methods to control mine gas and prevent coal and gas outburst. For soft and low-permeability coal seams, the hydraulic fracturing technology of cross-layer drilling is generally used to improve the permeability of large areas of coal seams [1-4]. However, for some mines without bottom drainage lane, the problems of bedding hydraulic fracturing, such as easy hole collapse, difficult hole formation, easy gas leakage in sealing hole and difficult pressure retention, lead to poor effect of bedding hydraulic fracturing technology. At present, the rapid development of directional drilling machine and the improvement of borehole sealing technology have brought a new opportunity for the segmenting fracturing technology of roof strike long borehole. In recent years, scholars have proposed the subsection hydraulic fracturing. Subsection hydraulic fracturing mainly through changing the mode of downhole hydraulic fracturing measures of force, the drilling can be divided into several segments, each segment set a high pressure water jet, the jet mouth, connect with water seal capsule, and each time will be fracturing pressure is focused on the point water injection, the scope of coal energy from the body into a point, to achieve the purpose of high voltage, small flow fracturing. Parallel control holes are arranged at the same time of pressure cracking [5,6]. In the process of fracturing, a set of artificial loose ring is set up to make the coal body within the scope of action produce a certain amount of displacement, and the cracks in the coal seam are expanded, so as to increase the permeability of the coal seam and improve the pre-extraction rate [7-10]. So, this topic starts from two aspects of technology and equipment, studies the

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segmenting fracturing technology of roof strike long borehole, and conducts field application in Wuyang coal mine to investigate the advantages of this technology.

2. Segmental Hydraulic Fracturing Technology

2.1 Segmental Hydraulic Fracturing Technology of the Middle Roof of the Working Face

Hydraulic fracturing construction in long hole section which in the roof of coal seam in 1~2 m, as shown in Fig.1, create a network of cracks similar to the ones formed in the roof of coal seam when the protective layer is mined, the gas stored in coal seam only needs a short distance migration to enter the fracture network of roof surrounding rock and be extracted, the maximum distance of the migration for the coal seam thickness. Through the implementation of segmental hydraulic fracturing, a uniform and developed fracture network can be opened in the roof rock strata, providing a "fast channel" for the gas migration in coal seams.

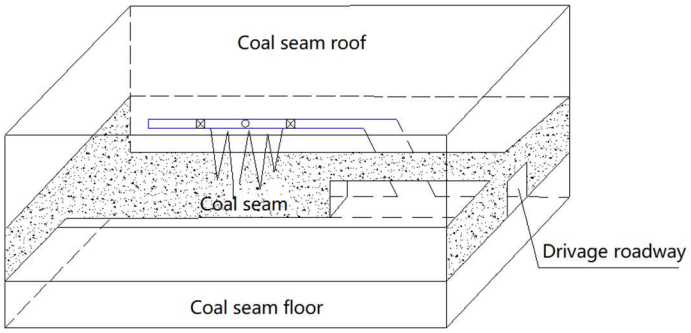

Fig.1 Segmental hydraulic fracturing of the middle roof of the working face

2.2 Reservoir Physical Characteristics

Table 1. Evaluation index of coal and rock reservoir reconstruction degree

Guidelines	Indicators	Evaluation		
		I	II	III
Geological structure	Tectonic stress zoning	Extension zone	Transition zone	Compressive zone
	Composite structure index	≤1.5	1.5~2.5	≥2.5
	In-situ stress	≤12	12~22	≥22
Coal seam gas	Gas content	≤6	12~6	≥12
	Gas pressure	≤0.6	0.6~1.2	≥1.2
	Rate of gas emission	≤8	8~20	≥20
Reservoir property	Coal body structure	Primary structure, cataclastic coal	To crush or shatter coal	Granular coal, mylonite coal
	Coal seam thickness	≤2	2~4	≥4
	Coal and rock fracture Cut density 1 strip /5cm	≥5	5~3	≤3
	Brittleness index	>50	30~50	<30
	Roof integrity	Loose and broken	chipped	complete
	Permeability of coal and rock	≥1	1~0.01	≤0.01

As shown in Table 1, coal rock reservoir evaluation index can be divided into I, II, III grade. I level of coal seam occurrence condition is stable, small gas content, easy gas extraction, extraction can be carried out when using conventional drilling process. II level of coal seam hydraulic disturbance process are necessary to increase the permeability, such as conventional hydraulic fracturing,

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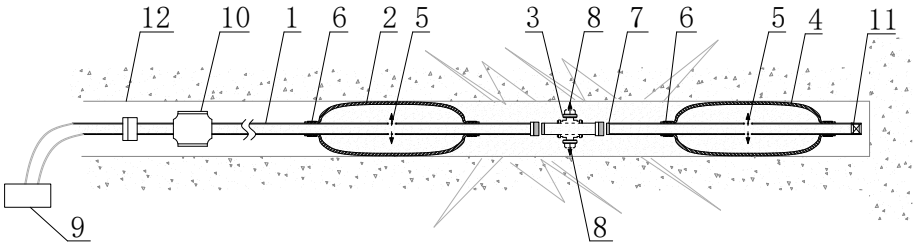
hydraulic punching. III level strengthen hydraulic disturbance techniques must be used for coal gas permeability, such as piecewise hydraulic fracturing. At the same time, the implementation of segmental hydraulic fracturing is closely related to the lithology of roof and floor of coal seam. For the hard coal seam, segmental fracturing can be directly carried out by segmental long drilling in the hard coal seam. For soft coal seam, staged hydraulic fracturing can be carried out in sandstone of roof of coal seam.

3. Key Equipment for Staged Hydraulic Fracturing

As one of the key tools of subsection hydraulic fracturing in underground coal mine, the sealing effect of the hole sealing device has a direct impact on whether the high pressure can be held up in the fracturing hole during hydraulic fracturing, it is the key to the success of coal seam network reconstruction. This time, an integrated segmented hydraulic fracturing borehole sealing device for downhole sealing and pressure sealing in coal mine is selected. With the traditional single span compared to a whole way of drilling hydraulic fracturing, the device adopts two packer capsule series connection way of dividing the whole drilling into several sections, each time will focus on a small piece of fracturing pressure, then according to certain order to hydraulic fracturing, due to the plane of action more concentrated, open cracks in the coal seam is more uniform, greatly improving the efficiency of fracturing, also reduced the water flow at the same time, which reduces the requirement for fracturing system, make the much smaller equipment, can better adapt to downhole conditions of roadway, the maneuverability is strong, easy technology popularization.



1- Coiled tubing, 2- First packer capsule, 3- Check valve, 4- Second packer capsule, 5- Drainage holes,

6- High pressure pipe hoop, 7- Thread, 8- Liquid injection hole, 9- Fracturing pump,

10- Orifice anchorage, 11- Plug, 12-Borehole

Fig.2 Hydraulic fracturing borehole packer with integrated sealing and pressure

As shown in Fig.2, the integrated segmented hydraulic fracturing device for underground sealing and pressure of coal mine includes the orifice anchorage device, the first pack capsule, the one-way valve and the second pack capsule arranged successively on coiled tubing [11]. Coiled tubing passes through the middle of the first and second packer capsules and water outlet holes are separated inside the capsules. The outer end of coiled tubing is connected with hydraulic fracturing pump, and the end is provided with wire plug; The packer capsule is fixedly connected with the coiled tubing through the high-pressure pipe hoop and the anti-outburst washer; The one-way valve is provided with two symmetrical liquid injection holes, and the one-way valve is connected with the coiled tubing thread buckle. The starting pressure of the one-way valve is 5MPa.

4. Field Test

4.1 Basic Information of the Test Site

In this test, the coal in Wuyang coal mine is soft and difficult to form holes, so it is not suitable for horizontal hydraulic fracturing. The lithology of its roof is mudstone, sandy mudstone, and local fine sandstone, which is qualified for segmental hydraulic fracturing of roof drilling. The test site was

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selected at 8006 working face, the target hole of segmenting fracturing was the comb drilling of the roof of drill yard No.4, and the target coal seam of fracturing was determined as No.3 coal seam. The average thickness of No.3 coal seam is 5.75m.

4.2 Segmented Hydraulic Fracturing Scheme Design

Drilling design and construction of two main branch drilling, of which, No.1 main branch hole opening in the coal seam to 20~30 meters into the upper strata above the roof of the coal seam construction to 250 meters, into the coal seam and along the upper middle of the coal seam construction to 350 meters; No.2 main branch hole opens branches at 30 meters, and works up to 150 meters along the strata above the roof of the coal seam, enters the coal seam and works up to 250 meters along the middle and upper part of the coal seam. Phi with a hole diameter of 98mm; the drilling rig model is VLD-1000 directional drilling rig, as shown in Fig.3.

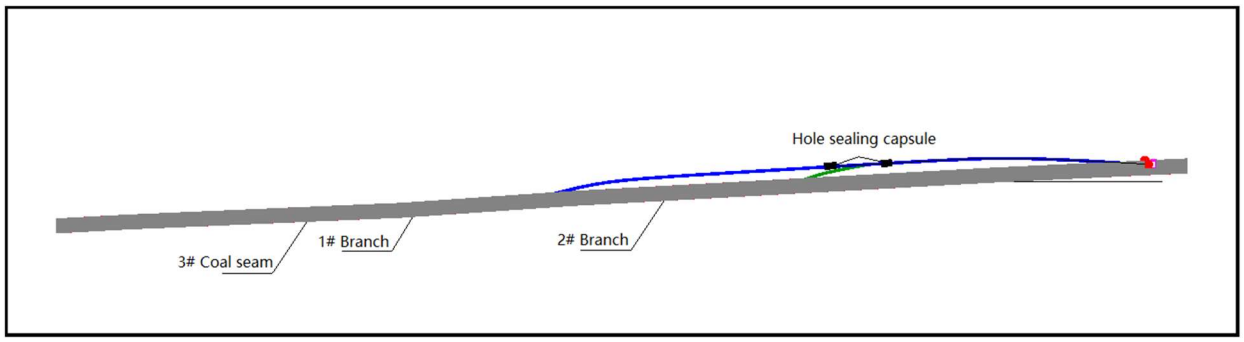

Fig.3 Borehole arrangement of segmented hydraulic fracturing

4.3 Hydraulic Fracturing

Hydraulic fracturing test was carried out on the directional branch fracturing borehole of the roof in the test area. As shown in Fig.4 and Fig.5, the total water pressure was 147m3, the pressure was stable at 18~23MPa, and the continuous pressure was 20MPa.The flow rate is stable at 28m³/h, and the fracturing time is 300 mins in total. During the fracturing process, the fracturing pump operates stably. After the fracturing is completed, it enters the field to observe that water seepage occurs on the roadway side.

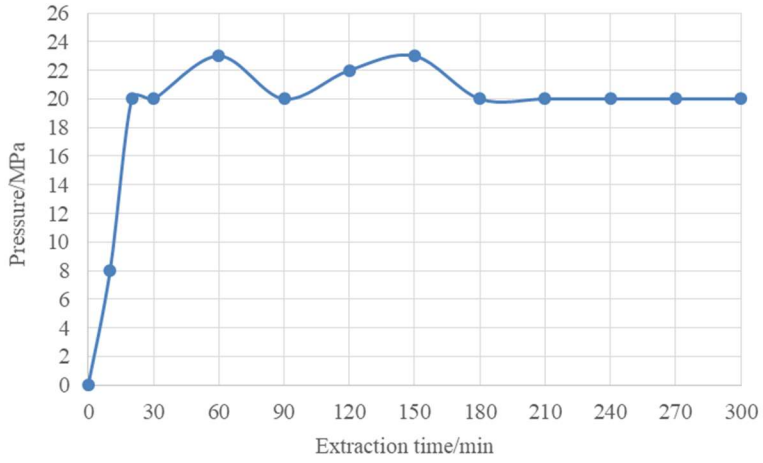

Fig.4 Pressure change curve

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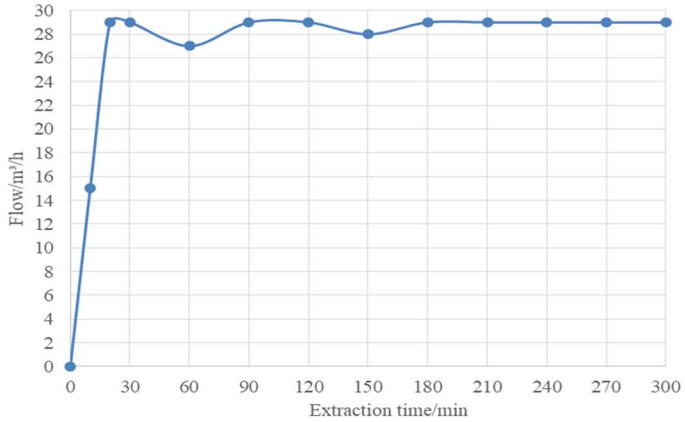

Fig.5 Flow change curve

4.4 Inspection of Extraction Effect

After 10 days of pressure maintaining for pressure cracking holes, by comparing the extraction data before and after hydraulic fracturing of pre-extraction boreholes, as shown in Fig.6 and Fig.7.

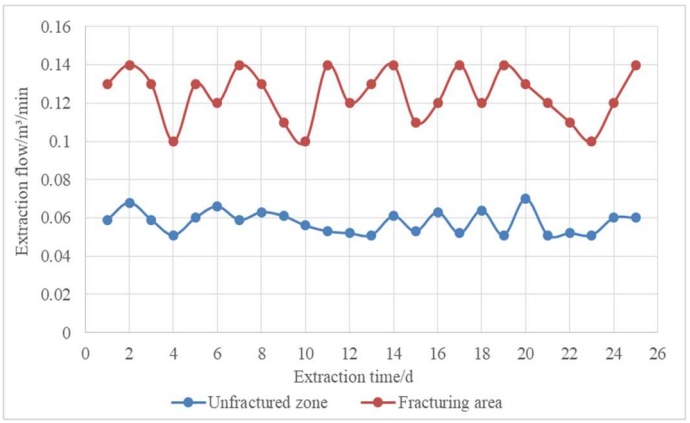

Fig.6 Extraction flow comparison

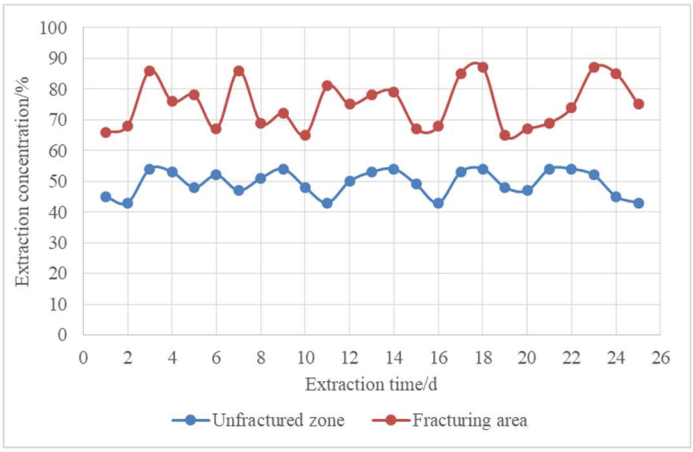

Fig.7 Extraction concentration comparison

From the Fig.6 and Fig.7, the average single-hole gas extraction flow was calculated to be 0.10~0.14 m3/min, and the extraction concentration was 65%~87%. In the drilling area without hydraulic fracturing, the average single-hole gas extraction purity was 0.051~0.068 m3/min, and the extraction concentration was 43%~54%. Compared with the drilling in the original coal seam, the average single-hole gas extraction purity in the hydraulic fracturing area is increased by more than twice, and

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the extraction concentration is increased by more than 30%. The extraction effect is significantly improved.

5. Conclusion

(1) Based on VLD-1000 directional drilling rig, fracturing pump group, segmented packer capsule and other equipment, as well as segmented delivery, drilling track monitoring and other technologies, the directional drilling segmented fracturing technology for roof of coal seam in underground coal mine has been formed;

(2) By comparing the extraction results, it was found that compared with the pre-extraction boreholes without fracturing, the average single-hole gas extraction purity was more than 2 times higher, the extraction concentration was more than 30% higher, and the extraction results were significantly improved, which verified the advantages of segmental hydraulic fracturing of the roof toward drilling.

Acknowledgments

This work is financially supported by China Coal Science and Industry Group Co., Ltd. Special Key Projects of Science and Technology Innovation and Entrepreneurship Funds(2022-2-TD-ZD009), Enterprise independent scientific research key research and development project(2022ZDXM11), which are gratefully acknowledged.

References

[1] Ma Shuyin. Study on Fracking Permeability enhancement process and gas comprehensive control effect [J]. Energy and Environmental Protection, 2023,45 (03): 134-139+143.

[2] Wang Hui. Research on subsection Fracking extraction technology of directional comb shaped long borehole in roof [J]. Shanxi Coal Mine, 2022,41 (06): 7-10.

[3] Yang Hongwei. Underground segmentation point hydraulic fracturing antireflection for low-permeability coal seams [J]. Journal of University of Science and Technology Beijing, 2012, 34 (11): 1235-1239.

[4] Li Qi. Experimental Study on hydraulic fracturing and penetration technology in Panbei coal mine [J]. Coal Technology, 2018, 37(2):212-213.

[5] Liu Liping. Application of directional drilling machines in coal mine gas control [J]. Coal, 2020,29 (08): 22-23+77+96.

[6] Yan Baoyong, Li Xinzheng. Application of ZYWL-4000D economical directional drilling rig in Pingshan Coal Mine [J]. Coal Technology, 2019,38 (09): 153-155.

[7] Sun Siqing, Li Wenbo, Zhang Jian, etal. Research progress and development trend of long borehole staged Fracking technology in coal mines [J]. Coal Geology and Exploration, 2022,50 (08): 1-15.

[8] Zhan Qingchao, Fu Wei, Song Haizhou. Study on the technology of directional long borehole staged Fracking for the huge thick roof of the coal seam in Dongtan Mine [J]. Coal and Chemical Industry, 2020,43 (11): 12-14+17.

[9] Zhang Fei, Ren Chunyu, Zhang Pei. Analysis and simulation of piecewise water pressure anti-reflection technology [J]. Coal Technology, 2016, 35(3):129-131.

[10] Zhang Chunhua, Zhang Yongzhi, Li Jiangtao, etal. Comparison analysis on permeability improved effect of single and multi-section hydraulic fracturing in deep depth seam [J]. Coal Science and Technology, 2017, 45 (6): 51-54.

[11] Zhang Pengwei, Liu Xiao, Ma Geng. Development of sealing and fracturing integration instrument for sectional hydraulic fracturing in coal mine underground [J]. Coal Technology, 2016, 35(11): 244-246.