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Research Status and Prospect of Hydraulic Fracturing Technology in Coal Mine

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Abstract

Hydraulic fracturing is one of the most effective methods to improve the permeability of coal seams at present. In order to promote the development of hydraulic fracturing technology in coal mines, the current development of hydraulic fracturing technology in coal mines is summarized from three aspects of hydraulic fracturing influencing factors, hydraulic fracturing methods and processes, and hydraulic fracturing effect evaluation. It is believed that the mechanism of hydraulic fracturing influencing factors, intelligent fracturing equipment, and systematic fracturing effect evaluation methods need further in-depth study.

Keywords

Coal Mine Safety; Hydraulic Fracturing Technology; Cracks; Intelligence; Impact Assessment.

1. Introduction

The vast majority of coal mines in China are underground mining, and there are many high gas mines and outburst mines, which bring huge challenges to gas control. China has accumulated a lot of practical experience in carrying out gas drainage, and the gas control technology has taken the lead in the world. In recent years, hydraulic fracturing, as a measure of pressure relief and permeability enhancement in coal seams, has been adopted by many mines and has achieved good application results. Especially in recent years, the number of CBM development wells in China has increased sharply, and hydraulic fracturing and permeability enhancement measures have been adopted for production [1]. At the same time, with the research of pressure relief and permeability enhancement technology for high gas and low permeability coal seams and the development of science and technology, it is shown that hydraulic fracturing technology has the characteristics of increasing the permeability of coal body, reducing ground stress and large pressure relief range, which provides a new way for gas control in outburst coal seams with low permeability and no protective layer mining. It is of great practical and long-term significance to improve the level of coal mine gas control and prevent coal mine gas accidents in China.

Hydraulic fracturing technology was first used in oil and gas fields, while the application of hydraulic fracturing technology in coal mines in China began in 1965 [2]. Coal mine hydraulic fracturing technology mainly refers to the use of water as the power to inject into the coal bed to promote the formation of different degrees of cracks in the coal bed, so as to achieve the purpose of improving the permeability. With the development of science and technology, coal mine hydraulic fracturing technology has been widely promoted and applied in Shanxi, Henan, Anhui, Shaanxi, Inner Mongolia and other regions, and has achieved good results [3]. The research of hydraulic fracturing technology in coal mines mainly focuses on the factors affecting

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fracturing, fracturing methods and technologies, and fracturing effect evaluation. In order to better promote the scientific development of coal mine hydraulic fracturing technology, the author summarizes the research status of this technology.

2. Research on Influence Factors of Hydraulic Fracturing

The structure of coal and rock mass has a significant impact on hydraulic fracturing. Chang Hong et al. [4] found that the hydraulic pressure effect is better when the coal body structure is primary coal and fractured coal compared with crushed coal. Sun Keming et al. [5] experimentally analyzed the influence of bedding inclination and strength on fracture crack propagation. Zhang Jian et al. [6] discussed the effect of natural fracture angle of 30 °, 45 ° and 60 ° on hydraulic fracturing fracture width, pore pressure and seepage velocity. At the same time, different hydraulic fracturing operation parameters also have different degrees of impact on its fracturing effect. Zhen Huaibin et al. [7] numerically analyzed the impact of perforation phase angle, geostress difference and elastic modulus on hydraulic fracturing fracture propagation. Tang Jupeng et al. [8] carried out true triaxial hydraulic fracturing test and found that the hydraulic fracturing effect is best when the horizontal ground stress difference and water injection pressure are close to 2.0MPa. Liu Le et al. [9] found that the fracturing effect is best when the fracturing fluid flow is 60 mL/min. Wang Yujie et al. [10] found through numerical simulation that the influence radius of fracturing increases with the increase of water injection pressure. Zhang Zhaoyi [11] studied the effect of fracturing water volume on the effective radius of fracturing through numerical simulation and field test, and believed that when the fracturing water volume reached 73.79m^3, the effective radius of fracturing was about 51m, and the fracturing effect was relatively optimal. Fu Haifeng [12] established a large-scale rock perforation and fracturing simulation physical test, analyzed the fracture initiation rules under different perforation modes, and found that the fixed plane perforation mode can improve the fluid injection efficiency of the hole more than the spiral perforation mode, and reduce the fracture extension pressure by up to 25%. Li Quangui et al. [13-14] studied the impact of pulsating flow rate of 50mL/min, 75mL/min, static pressure fracturing, 1Hz, 10Hz and other different pulse frequencies on pulsating hydraulic fracturing, and found that pulsating frequency and flow rate have some similarities in the effect. The lower the two, the lower the fracture pressure, and the more developed the fracture. Dong Kangxing et al. [15] discussed the influence of pulse cycle number, pulse amplitude and other parameters on fracturing initiation pressure. Yang Yongming et al. [16] studied the impact of perforation density, hole distribution mode, hole diameter, depth and other sandstone hydraulic fracture morphology, and found that perforation density, hole depth, and hole diameter have a greater impact on fracture pressure, while the impact of control mode is not significant. Jiao Zixi et al. [17] carried out the sandstone hydraulic fracturing simulation test under the effect of different fracturing fluid viscosity, and found that the fracture morphology caused by different fracturing fluid concentration is also different, and the fracture pressure increases with the increase of fracturing fluid viscosity.

3. Hydraulic Fracturing Technology and Field Application

With the application of hydraulic fracturing technology and the progress of science and technology, higher requirements are put forward for the performance of fracturing equipment and fracturing technology. Different application requirements lead to the continuous development of fracturing technology, such as sanding hydraulic fracturing technology, repeated hydraulic fracturing technology, staged hydraulic fracturing technology, etc. Xu Yaobo [18] developed a combined stimulation technology based on liquid nitrogen injection assisted hydraulic fracturing, and carried out a pilot test in Luling Mining Area, Huaibei, with an increase of 50%. Liu Xiao et al. [19] used HTB hydraulic fracturing pump set to carry out repeated fracturing field test in Zhongmachun Mine, and found that the permeability coefficient of coal seam increased from 3.2~4.0 $m^2/(MPa^2.d)$ to 25.6~44.8 $m^2/(MPa^2.d)$. Meng Xiaohong [20] carried out hydraulic fracturing field test in Chengzhuang Mine in combination with the optimization of drilling layout, and the permeability coefficient of coal seam after fracturing increased by 26.3 times. Li Xiyuan et al. [21] implemented the repeated hydraulic fracturing technology of "less water injection and multiple fracturing" in Pingdingshan No.12 Coal Mine, and found that the reduction of coal seam gas content was much higher than that of single fracturing. Xu Hongjie [22] carried out the field test of the top coal weakening technology based on "drilling cutting pressure" directional hydraulic fracturing in Shenshupan Coal Mine of Yushen Mining Area, and the fracture development degree of the top coal after fracturing increased by 23.5%. Jia Bingyi et al. [23] developed a continuous hydraulic sand fracturing equipment with an overall pressure of up to 55MPa and a one-time sand loading of 750Kg. Through the field test in Pansan Coal Mine, Huainan, Anhui Province, it was found that after the implementation of this technology, compared with clean water fracturing drilling, the gas extraction volume and net gas extraction volume of 100 holes in sand fracturing drilling increased by 2.38 and 2.03 times. Lv Yulei [24] et al. proposed the roof directional long borehole staged fracturing technology to carry out advanced regional weakening and risk relief treatment, and the application effect in Ordos mining area is remarkable. Liu Le et al. [25] developed a new composite fracturing technology of "directional sand blasting and perforating+sanding staged fracturing", aiming at the problems of uneven and small coverage of conventional hydraulic fracturing, and conducted industrial tests in Xinjing Mine, Shanxi Province. It was found that this technology can achieve large displacement, continuous operation and obvious fracturing effect.

4. Hydraulic Fracturing Effect Evaluation

How to evaluate the effectiveness of hydraulic fracturing after its implementation is the key work, and accurate effect evaluation will help the development and promotion of technology. Wang Huiqing, Bai Li, et al. [26-27] proposed the evaluation of micro-seismic method in hydraulic fracturing effect. Dai Zhixu [28] proposed a downhole hydraulic fracturing tracer monitoring technology based on ammonium thiocyanate. Zhu Quanjie et al. [29] proposed a characterization method of hydraulic fracturing effect based on microseismic indicators. Yan Jiangping [30] used the underground microseismic monitoring technology to monitor the impact range after hydraulic fracturing in the coal mine. Through comparison with the traditional borehole observation method, it was found that the fracturing damage range delineated by the microseismic monitoring results was smaller and the accuracy was improved. Yuan Yongbang et al. [31] studied the influence range and effect of 0.3, 0.5 and 1.5 MHz electromagnetic waves on coal seam hydraulic fracturing, and proposed a fracturing effect evaluation method based on multi-frequency synchronous electromagnetic wave CT technology. Zhao Rui et al. [32] used the borehole transient electromagnetic three-component detection method to detect and evaluate the distribution of fracturing fluid before and after fracturing. Heichuang et al. [33] proposed a hydraulic fracturing effect evaluation method based on the scattered wave energy of the borehole. Li Yan [34] carried out the application of hydraulic fracturing on the roof of Working Face 402 of Hongqinghe Coal Mine, analyzed the fracture distribution pattern using skewness and kurtosis, and evaluated the change of roof impact risk using microseismic energy and b value. Zhong Kun et al. [35] used the SOS microseismic system and the fiber bragg grating three-dimensional stress long-term dynamic monitoring system to conduct real-time monitoring of microseismic events and stress before and after hydraulic fracturing of the roof, and found that the stress concentration of the roof

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rock stratum was significantly reduced and the microseismic events were significantly reduced after fracturing.

5. Conclusion

According to the above research, the hydraulic fracturing technology still has the following deficiencies:

(1) The mechanism of the influence of water injection pressure, time and water injection volume on fracture propagation in hydraulic fracturing process is not deep enough, and the influence of coal and rock deformation is ignored in the process of fracture propagation research. At the same time, the factors to be considered are relatively single, so the next step should be to consider the study of hydraulic fracturing mechanism under the coupling influence of multiple influencing factors.

(2) At present, the accuracy, stability and intelligence level of hydraulic fracturing technology and equipment are insufficient, and the accuracy of existing technical methods needs to be improved. It is urgent to focus on improving the intelligence level of hydraulic fracturing equipment.

(3) At present, the post-hydraulic fracturing effect evaluation method is relatively simple and not systematic. A complete and systematic effect evaluation method is required for hydraulic fracturing parameters and fracturing effect.

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