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The Analysis of Key Issues for Virtual Reservoirs Application in Coalbed Methane Development

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Based on flow state of coalbed methane (CBM) migration, coal reservoir broadly is divided into outburst and non-outburst coal. Because of strong water sensitivity and poor hydraulic fracturing effect of outburst coal, hydraulic fracturing measures to increase permeability which used to be applied in non-outburst coal do not suitable for outburst coal. Coal floor is selected as virtual reservoir for roof maintenance when mining coal, Depending on a zero radius drilling and high-energy gas loose blasting technology, the reservoir and the coal floor become transfixion, so that the CBM diffuse to the floor cracks, and then migrate into the wellbore. The "highway" of CBM migration is built through virtual reservoir, which would be expected to break through the forbidden zone of traditional CBM development, and joint two-energy exploitation of coal and CBM can achieve, so that gas disaster and greenhouse gas emission will reduce greatly. Therefore, virtual reservoir has broad application prospect.

Keywords : Virtual reservoir, CBM, Outburst coal and non-outburst coal, Zero-radius drilling, Loose blasting

1 INTRODUCTION

According to the mechanical properties of coal seam, coal is divided into four categories: undeformed and cataclastic coal, where coal and gas outburst hardly appear, belongs to non-outburst coal; granulitic and mylonitic coal, which are prerequisites of coal and gas outburst, therefore are grouped into outburst coal. So far, CBM development object is non-outburst coal, but the above outburst coal where gas disaster is prone to happen still is the forbidden zone.

In the past, CBM development process in non-outburst coal aimed at increasing the reservoir permeability, and the hydraulic fracturing is the most commonly technology. High-pressure water is driven to squeeze into the coal, which includes original and new fracturing cracks. With the widening and extending of

these cracks, thus more secondary cracks and fissures generate and increase the coal seam permeability, which is currently the principal means of CBM development. But the above measures are not applicable to outburst coal because of no residual mechanical strength in the outburst coal, so any conductive crack can not be formed. While outburst coal encountering fracturing fluid-water, permeability sharply reduce as coal become clumps or paste-like, which will badly hinder the migration of CBM production, and coal power pulsing will be liable to backflow in later drainage and gas production stage. Therefore, how to develop CBM in outburst coal, the complete elimination of coal and gas outburst hazard is a problem demanding prompt solution.

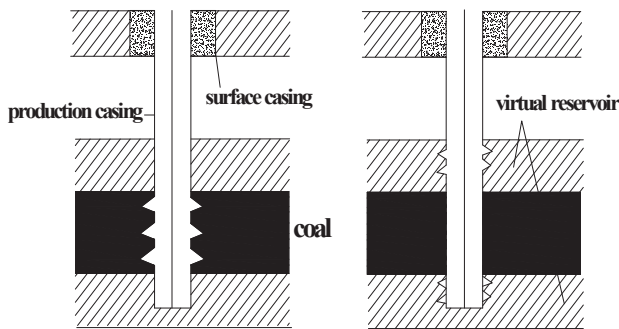
2 THE PRINCIPLES OF VIRTUAL RESERVOIR

CBM migration is a two-stage diffusion in outburst coal, where seepage never happen, which is

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the basic flow pattern in non-outburst coal. Gas output is very slow and attenuation coefficient is large, which leads to the poor drainage and small drainage radius. The key to solve the problem is how to build the flow "highway" to reduce the distance of CBM diffusion.

With conventional CBM development process, the key of virtual reservoir development process is that gas does not directly migrate into shaft, but an indirect seepage into the shaft through virtual reservoir-roof and floor. By hydraulic fracturing or the open-hole cavity completion in virtual reservoir, its permeability and connectivity with coal seam remarkably increase. CBM desorbed from coal spreads to the virtual reservoir in the shortest possible time, then through virtual reservoir migrate into the shaft in seepage pattern, the two CBM development models are shown in Fig. 1.



(a) conventional model (b) virtual reservoir model

Fig. 1 The comparison of two models

At present, mining protective seam and gas drainage by high level borehole are widely used in coal mine, which already is proven effective measures. Its basic principle is the same as a virtual reservoir, where gas is not directly drawn out from the coal, but the migration to the "virtual reservoir" is discharged to reach the gas disaster control. The difference is that the virtual reservoir process of CBM development is carried out on the ground, but mining protective seam and gas drainage by high level borehole are underground drainage projects.

3 THE ANALYSIS OF KEY ISSUES

3.1 The selection of a virtual reservoir

Coal seam structure and the impact on the late coal mining must be considered while the appropriate virtual reservoir is selected, and mainly the following three situations:

(1) Aiming at West Henan II_1 coal, the entire coal seam is outburst coal (granulitic and mylonitic coal), so the permeability rate is less than $n \times 10^{-6} \text{ um}^2$. If the coal roof is relatively complete, coal floor is chosen as a

virtual reservoir in order to maintain roof when mining. If the coal roof has been broken, the roof is directly chosen as a virtual reservoir.

(2) Aiming at the Pingdingshan 9-10# coal, the upper is undeformed and cataclastic coal, but the lower is granulitic and mylonitic coal, and the upper is chosen as a virtual reservoir to develop CBM of an entire coal seam.

(3) For multi-seam and small distance between the coal seams, the sandwich between the two coal seams directly is selected as a virtual reservoir.

3.2 The enhancement methods for virtual reservoir

If coal roof is broken, where permeability is favorable and is served as a virtual reservoir, so enhancement methods is needless. But most roof and floor of the coal seam is relatively complete, the floor is selected as a virtual reservoir for roof support in late mining coal, but the enhancement method is different from conventional CBM well.

Conventional hydraulic fracturing used in CBM development does not apply the virtual reservoir, on account of the low young's modulus and large poisson's ratio of the coal with roof and floor. During hydraulic fracturing coal reservoir, the roof and floor is a good "barrier", therefore cracks and fissures can extend far only in coal reservoir. But the virtual reservoir is on the contrary, if the hydraulic fracturing is implemented, it can not ensure that cracks can extend a certain distance only in the virtual reservoir⁽¹⁾⁽²⁾. At the same time the water sensitivity of granulitic and mylonitic coal is very strong, the permeability will decrease sharply when encountering water, and coal power pulsing takes seriously in late drainage and gas production stage.

Loose blasting and high-energy gas fracturing technology have been successfully applied in oil and gas field for many years⁽³⁾⁻⁽⁷⁾. It makes use of gunpowder or propellant burning by control, producing high temperature and pressure gas, which is a lot more than the largest in-situ stress of reservoir, and takes pulse mode load acting on the reservoir, so that the fracture occurs and forms many radial cracks without the influence of in-situ stress. It is mainly used for plugging removal near well bore area, and is characterized by no water participation, and cracks can be supported automatically.

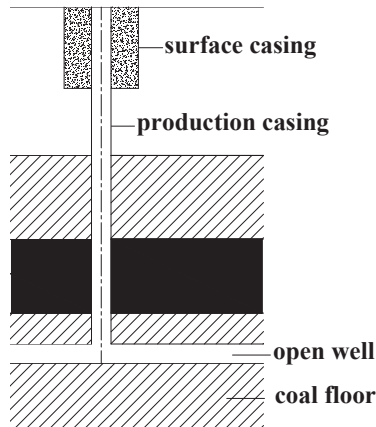
To the complete coal roof and floor, zero-radius drilling techniques can be used and horizontal boreholes extended a certain distance in several directions in the coal floor, and then a certain amount of high explosive are placed per some distances in open hole well, which is ignited and blasting. The technical parameters of implementing the loose blasting are to boost time and peak pressure, which is remarkably important to cracks form and shaft safety, so it is crucial to control these two parameters.

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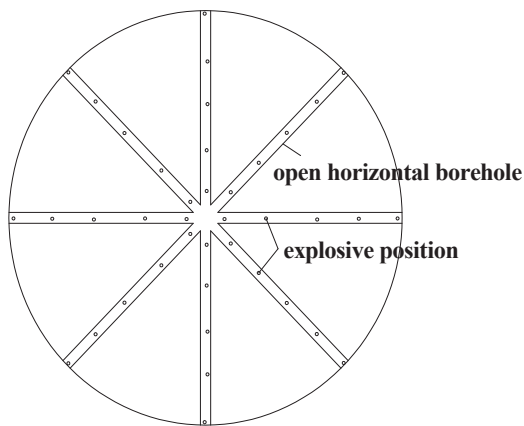
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(a) View for the front



(b) View from the top

Fig.2 Loose blasting diagram

4 CONCLUSIONS

(1) How to develop CBM of outburst coal has been thinking about in the CBM industry for a long time, but it has not yet entered the project implementation stage so far. Because of great differences in CBM migration mechanism, reservoir enhancement model and water sensitivity between outburst and non-outburst coal, conventional CBM development process does not apply.

(2) The key to develop CBM in outburst coal is virtual reservoir choice and reservoir enhancement model. Based on coal structure and the impact of late mining, virtual reservoir include three cases: roof and floor, undeformed and cataclastic coal and sandwich between two coal seams. As “barrier” does not exist, cracks extension by the hydraulic fracturing can not realize absolutely. Conclusion can be obtained that hydraulic fracturing does not apply to a virtual reservoir, while the loose blasting technology for virtual reservoir has a broad application prospects