



DRAINAGE METHODS OF COAL BED METHANE AND ITS APPLICATION IN JINCHENG MINE FIELD IN CHINA

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ABSTRACT

Gas is one of the biggest threatens to safety production in coal mine and the destructor of humans' living environment, so the efficiency drainage before mining and using of CBM has been paid more attentions. In allusion to the complicated geologic particularities of CBM occurrence in China such as: low reservoir pressure, poor permeability and low saturation and so on, the current drainage methods of CBM and its relative merits are discussed in this paper, which include: gas drawing underground, surface vertical well suction, simultaneous extraction of gas and coal, and gas drainage from abandoned coal mine etc. Besides, the applicability of these methods is probed by integrating the specific condition of Jincheng coal mine area in China. The investigation results provide reference for efficiency drainage and utilization of CBM in China.

Key words: CBM, drainage before mining, vertical well surface suction, simultaneous extraction of gas and coal, Jincheng coal mine area.

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INTRODUCTION

The Coal Bed Methane (CBM) is also called gas, which is unconventionality natural gas reserved in coalbed and one important succeeds energy resource in the 21st century. Developing and using the CBM are not only significant for reforming the energy structure and protecting atmospheric environment, but also can prevent gas-disaster fundamentally and improve the coal mine safety conditions. The CBM resource in China is extremely abundance. According to calculating, the total amount is about $43 \times 10^{12} \text{m}^3$ which is almost correspondence to that of natural gas, ranks the second in the world. Furthermore, most CBM resources in China distribute along the pipeline of West-East natural gas transmission project, and the potential exploitation capacity is greatness [1].

However, gas explosion accidents are the biggest threatens to safety production in coal mine, and these accidents have token huge damages to China especially. As we know that the main component of CBM is CH_4 , which brings 22times greenhouse effect and 7times destructiveness to ozone layer more than CO_2 . The drainage quantity is bigger and bigger

year by year in the worlds, which have resulted serious damages to the atmospheric environment [2]. Therefore, more attentions had been paid to effective harnessing gas and controlling the accidents. In this paper, the current drainage methods of CBM in China and its relative merits are emphasis introduced according to the CBM reservoir geologic particularities; and the applicability is discussed based on the specific condition of Jincheng mine field, which can provide some reference to CBM drainage in China.

CBM RESERVOIR GEOLOGICAL CHARACTERISTICS IN CHINA

It is an important milestone of world oil-gas industry that taking CBM as natural gas resource for commercial production. At present, CBM drainage in China has already stepped into the starting stage of commercial production, and China is transferring from possessing substantial CBM to high yielding. In the exploration process, fundamental observations of geologic particularities of CBM are extremely deepened, and notable progresses in basic research of exploration and development technology are obtained [3]. The coal reservoirs in China have its natural and special storage capability, which effected by multiple superposition crustal movements and complicated various tectonic activities, so the characteristics in most coal reservoirs in China are as follows [4]:

- (1) Low reservoir pressure, poor permeability and low saturation; some areas appear as exceptional low pressure, permeability and saturation.
- (2) Regionally appeared pulverized coal lenses, so that the motivation process of reservoir reforming can't be carried out which take effect on capacity of CBM wells.
- (3) The intensive heterogeneity of most medium-rank coal reservoirs has seriously limited the production of CBM wells, and brings big difficulties to scale development.
- (4) There are high tectonic stresses in most coalfields. These conditions decline the permeability of coal reservoirs, and accelerate the unbalance couple of coal-water-gas.
- (5) High gas productivity has been obtained from high-rank coals, which shows that not all high-rank coal is dead zone in CBM development.

If the above special characteristics were judged by the theoretical system existing in America, there are no productions in almost coal areas in China. Whereas, the experiment on exploring and developing CBM in such areas: Jincheng, Hedong, Dacheng and Tiefa have been achieved in a great success and a huge development potential of CBM resources has been further revealed in China.

DRAINAGE METHODS OF CBM IN CHINA

In recent years, people have paid more attentions to the coalmine safety, resource utilization and environmental protection etc; particularly the gas has been the key cause to mine accidents, so that the CBM industry has been fast developed in China. The drainage activities have been through half a century with the theme of prevention and control of gas hazard. With the in-depth study, several main technological methods are invented to drainage CBM with theory integrating practice, which are: surface vertical well suction, underground methane suction, simultaneous extraction of coal and gas, and gas drainage

from abandoned coal mine etc. In order to meet the requirements of the production of high gas mine, drainage before mining and simultaneous extraction of coal and gas are becoming more and more important.

Surface vertical well suction

This suction method is like that: drill a well into coal bed from ground, make the adsorbed gas desorbed from coal bed and flow to the ground along well by drainage and pressure-lowering, besides, use the natural pressure drop or gas pumping unit to extract the CBM which relicts and congregates in rocks under the influence of mining, unexcavated coal beds and gobs. Based on weather the coal reservoirs are affected by the mining, the method can be classified into conventional vertical well suction and surface drilling drainage in mining influence zone. The former requires big thickness coal seams, good permeability and favorable topography. However, the permeability of coal reservoirs in China is generally poor, so the fracturing and opening hole cavity in coal reservoirs are needed to improve the production [5]. This drainage method has the advantages such as high production, high recovery ratio, and excellent maneuverability and scale benefits. The main stimulation measures are: hydraulic fracturing, displacement of multi-gas and oriented pinnate horizontal well-drilling et al [6].

Underground methane suction

This method is that: drill in drift and drainage CBM by negative pressure caused by gas pumping unit from the ground. Nowadays, there are more than 600 workplaces where CBM have been draining in China, the suction quantity was beyond $16 \times 10^9 \text{ m}^3$ in 2004, but the utilization percent is only about 50% for the lack of pipelines. For the more, the small scale of drainage, low ratio of extraction, lagged management level and technical arrangement, inefficient utilization are the characteristics of this method. The main technologies of underground methane suction are as follows [5, 7]:

- (1) Gas drainage from the seams being mined: layers drilling hole, parallel boreholes, cross-brothel, borehole-net boreholes, deep-hole pre-splitting blasting, hydraulic slit-cut, hydraulic fracturing etc.
- (2) Gas drainage from adjacent seams: layers drilling holes in roofs and roads, long horizontal roof rock hole etc.
- (3) Gas drainage from gobs: caving zone boreholes, drainage by embedded pipe and surface drainage.

The adaptability of this method is abroad, and it requires no advanced technology and little investment. At present, the underground methane suction is one of the main measures to prevent coal and gas outburst and the effective approach for decreasing the gas emission in gob, and the method is the development mode which has being made great environmental, economic and social benefits. Furthermore, the method has been changed from unitary drainage for safety to energy sources-safety-environment protection, and remarkable progresses have been made, and comprehensive drainage should be expanded and applied

extensively, together with the underground methane suction and surface drainage in mining areas, meanwhile, improving and perfecting the drainage equipments should be enhanced.

Simultaneous extraction of gas and coal

The CBM is absorbed in organic reservoirs by rock pressure and the adsorptive capacity of coal bed, and disturbed easily by extrinsic factor, so the key technology of drainage should be around 'protecting reservoirs, decreasing damage to reservoirs'. Simultaneous extraction of gas and coal, which makes the most of released stress field and stimulation of hydraulic fracturing should not implemented, decreases the influence of jam by coal dust for one hand, and for another hand, decreases the damage to coal reservoirs. At the same time, the most of CBM (more than 70%) are extracted in a short run, which not only figure out the gas problems fundamentally in mine, but also solve the problems of long gas recovery cycle, slow recompense of funds in conventional technologies.

The precondition of this method is multi-seam mining and the order of mining is from bottom to top. The main conceive is: layout surface vertical well in mining range. Before exploitation, pre-drainage the CBM in mining coal seams and adjacent coal reservoirs by conventional surface vertical well; And then, drainage the CBM from adjacent coal reservoirs influenced by mining and released from mining seams; At last, drainage from gob after mining. When extracting the upside coal seams, the drainage process are repeated. Mining coupled with the whole gas production, so this method is called simultaneous extraction of coal and gas. The bests of this method are: coal seams are under the influence of depressurization all the time except the first pre-drainage, which can increase the extraction ratio significantly [8, 9].

Simultaneous extraction of coal and gas can be divided into 3 stages as follows: pre-drainage the CBM in indigenous coal reservoirs at first; then drainage from area of mining influence; finally, drainage from gob. These 3 stages are in one whole process, which need repeated continuously and can't be separated. Thus, simultaneous extraction of coal and gas is one feasible way worthwhile to attempt for the coal with poor permeability.

Gas drainage from abandoned coal mine

This method is that: drainage and using CBM from abandoned coal mine, which are residual and gather in rock and coal seams. This is one new way to extract CBM in China, which is at its beginning and still under study, improvement and perfect. This method is low costs because there are no new wells and fracture reform to reservoirs, and no contradiction with production of coal mine. However, it is difficult to be industrialized and large-scale production for the lack of this resource [5].

From above analyses, the surface vertical well may be industrialized and large-scale production. Whereas, there is geologic limitation in that method because the particularity of geologic condition and reservoir physical property in China, and simultaneous extraction of coal and gas, which can make up the deficiency of that method effectively, are the important technology for industrialized development of CBM.

APPLICATION AND DRAINAGE METHODS OF CBM IN JINCHENG, CHINA

Jincheng possesses rich CBM resources, and the high gas mines are in the west, which have the outbursts prone of coal and gas. In recent years, Jincheng Coal Industry Group has made remarkable effects in gas control by pre-drainage from surface and fracturing, which deduced the gas accidents in mine production. The principle that drainage CBM is servicing for safety production is established, and a new way of drainage from surface and underground simultaneously, drainage and utilization equality, integrated coal extraction and gas production is built up.

Application of simultaneous extraction of coal and gas in Jincheng mine field

In Jincheng mine field, a new way to recover CBM that is the CBM mine has been put forward according the practical situations integrated with the idea of simultaneous extraction of coal and gas.

The opening way of CBM mine is main shaft. Every coal extraction tunnel is a stope of CBM in coalmine, and every stope is composed of water-seal switching gate, coal extraction tunnel, drills and gas well, etc.

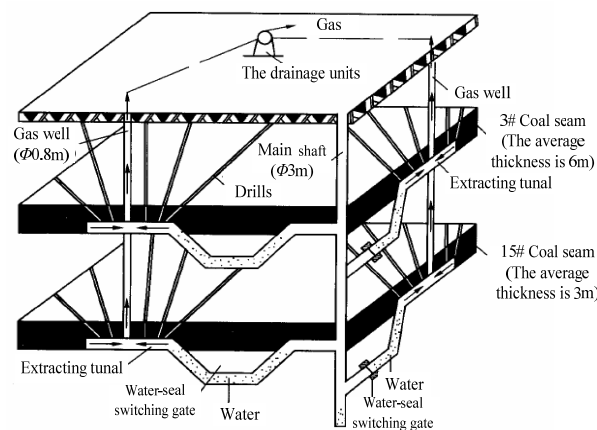


Figure 1.: The CBM mine

The technical characteristics of CBM mine are: (1) the mine is developed to gas recovery from coal extraction; (2) the gas recovery is turned from for mine safety to gas production with the region of gas drainage is enlarged, system is simplified, recovery ratio of gas is raised to 95%, methane concentration is over 95%, investment and cost in gas suction system capability are reduced; (3) The drainage technology is developed from surface drilling drainage by positive pressure to drainage under mine by minus pressure and the drainage process is from uncontrolled to controlled overall process. Therefore, gas generating capacity in per area is increased; theoretic recovery ratio of gas is raised from 27% to 95%, investment in gas suction capability is dropped down from ¥5/m³ to ¥0.5/m³.

According to the geologic conditions of Jincheng, the opening way of mine is main shaft, constructing 4 CBM stopes in 3[#] and 15[#] coalseams. In every stope, whopping gas before digging is carried out by 1000m drilling machine together with parallel-brothel in two sides of extracting tunnel, where the coal seam methane content is more than 9m³/t.

Application of surface drilling drainage in Jincheng mine fields

Jincheng Coal Industry Group has devoted to pre-drainage on the ground before excavation since the beginning of 1990's, fruitful experiences have been accumulated through perennial production practice, and large number of qualified management and technical talents working on the exploitation and utilization of CBM are trained. Up to now, more than 150 CBM wells have been constructed and put into service in Panzhuang mine field, another 300 CBM wells are being constructed and will be put into service gradually in few years, then the total number of CBM wells will be 450 and the annual gas production will reach to $2.5\sim 3\times 10^9\text{m}^3$. Until the end of the Eleventh Five-year-plan, it will be the biggest CBM wells net in China which the number of wells will be 2000, the annual gas production will be $16\times 10^9\text{m}^3$. In addition, the technology of free water drilling, active water fracturing was mouse out by the Group based on advanced technology at home and abroad, meanwhile, the surface development technology and commercial development model with independent patent property right are created by great improvement in several shafts, e.g. drilling, cementing, well logging, fracturing and drainage.

The basic thinking about drainage technology of vertical well is water drainage-pressure declining-desorption-gas production, and the output process of CBM includes 3 steps, e.g. desorption, diffusion and percolation. The geological characteristics and generation mechanism of CBM are further researched. Based upon the previous experience of success, the control theory and craft of constant pressure drainage have been created in order to control the sand spitting better and insure the gas well stabled and sustaining high yield, which makes the gas well in its best situation. In the process of drainage, the bottomhole flowing pressure and the pressure difference between bottomhole and reservoir are controlled by adjusting the water production and casing pressure in wellhead. The process of drainage includes 3 stages: the first is to keep the well flow capacity of fractured cracks; the second is to keep low flowing pressure of wells reasonable; and the last is stable production. The process analysis should be taken in process of drainage and working schedule should be made reasonable so as to improve the drainage effect of CBM wells.

Application of underground methane suction in Jincheng mine field

In Jincheng mine field, permanence gas extraction system was built in Sihe mine in May, 2000. In order to improve the extraction effect, the first booster station underground was built in 2002, which can increase the CBM production greatly. At present, the actual suction quantity is 120m³/min, the annual suction quantity is 63hm³(purred), and it reached 130hm³ in 2005. For the purpose of building a sustainable development energy system integrated resource, energy and environment, making the most of low concentration CBM

(45%~55%) recovered from underground, the gas power generation model project whose total installed gross capacity is 1.1×10^4 kW had been constructed, gas power plant with the capacity of 120MW has been programmed and under constructing now[11].

The gas extraction underground in Sihe mine includes two sides: drainage in tunnel drilling and drainage in working face. For the former, Sihe mine is a high gas mine, gushing out amount of gas in 100m tunnel exposed newly is $0.3 \sim 0.6 \text{ m}^3/\text{min}$, and it can be over $10 \sim 15 \text{ m}^3/\text{min}$ if geological structure and the unusual gas gush were encountered. Therefore, the drill shacks are laid out every 200m on sidewalls and drillings are distributed in sector so that the gas gush quantity can be reduced. The method can cut the quantity of gas gush in one-end tunnel down from $9 \sim 10 \text{ m}^3/\text{min}$ to $5 \text{ m}^3/\text{min}$, which ensuring the safety extraction. For the latter, drainage from drills distributed along the coal seam is dominant and drainage from gobs is secondary for gas extraction. Thus, the suction quantity in only one high long wall face is $60 \sim 70 \text{ m}^3/\text{min}$ and the recovery ratio is as high as 40% by improving the borehole seal, increasing the minus pressure in borehole top and enhancing drainage from pressure released zone.

There is no abandoned coal mine in Jincheng mine fields, so drainage method of gas drainage from abandoned coal mine is not applied, but the residual gas in gobs can be whopped by the vertical well using to drainage before mining.

CONCLUSIONS AND PROSPECTS

- (1) The particular geological characteristics of CBM in China are: low reservoir pressure, poor permeability, low saturation, tectonic coal developed and high productivity gas flow was obtained from high-rank coals.
- (2) The main drainage methods include surface vertical well suction, underground methane suction, simultaneous extraction of coal and gas, and gas drainage from abandoned coal mine etc, the suitable method should be chosen according to specific circumstances of mining area.
- (3) A new drainage method is put forward in Jincheng mine fields, which is the CMM mine. The new production mode of 'drainage from surface and underground simultaneously, drainage and utilization equality, integrated coal extraction and gas production' is formed, which guided by 'drainage CBM is serving for safety production'.
- (4) The above several methods are widely applied in Jincheng mine fields. The underground methane suction is comparative maturity; the surface vertical well is improved greatly as well which get gradually scaled; gas production are increased year by year. All of these methods provide strong secure for mine safety production.

The CBM is a kind of green power sources, the main causations of coal mine accidents. Thus, industrialization development of CBM must be enforced, which not only provides a new way for the thorough solution of mining accidents, but also can lyses the pressing status of energy shortage in China and reduce environment pollution. There is redundant of CBM resource in China with the complicated geological storage conditions, the

development methods should be chosen scientifically basis of practical situation. The scaled, industrialization development must become true integrated with strengthening the basic theory research and state preferential policies!

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