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Drainage and utilization of Chinese coal mine methane with a coal–methane co-exploitation model: Analysis and projections

Lei Wang, Yuan-Ping Cheng *

National Engineering Research Center for Coal Gas Control, China University of Mining and Technology, Xuzhou, Jiangsu 221116, China

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ABSTRACT

Coal mine methane (CMM) released during coal mining attributes to unsafe working conditions and environmental impact. China, the largest coal producer in the world, is facing problems associated with CMM such as fatal gas accidents and intense greenhouse gas emission along the path to deep mining. Complicated geological conditions featured with low permeability, high gas pressure and gas content of Chinese coal seams have been hindering the coal extraction. To solve these problems, a model of coal–methane co-exploitation is proposed. This model realizes the extraction of two resources with safety ensured and has been successfully applied in Huainan coalfield, China. The current situation of drainage and utilization of CMM in China are diagnosed. Connections between the coal production, methane emissions, drainage and utilization are analyzed. Estimations of future coal production, methane emissions, drainage and utilization are made in a co-exploitation based scenario. The emitted, drained and utilized CMM are projected to reach 26.6, 13.3 and 9.3 billion m^3, respectively by adapting the assumption of 3800 million metric tons of coal production by 2020.

Introduction

Powered by robust economic development, China has become the world's second largest energy producer and consumer (NBSC, 2009). Coal, as a primary energy source, accounts for 70% of the nation's total energy supply (BP, 2010). The Chinese coal production has increased significantly from 1299 million metric tons (Mt) in 2000 to 3050 Mt in 2009, an annual growth rate of 10% (BP, 2010). It is foreseen that coal will still play a leading role in the energy structure of China for a long time.

While the contributions from coal mining industry to Chinese energy supply are irreplaceable, the conditions for coal exploitation are deteriorating. With the continued dependence on coal production, coal extraction is expected to become increasingly challenging as shallow reserves are exhausted and deeper and more gassy seams are mined (U.N. ECE and M2M, 2010). The deeper mining levels are increasing the emissions of coal mine methane (CMM), which could lead to serious mining accidents like outbursts.

The CMM involved accidents are the dominant cause that is threatening mining safety. They account for 45.8% of severe coal mine accidents where there are more than ten fatalities, according to the 2010 China's coal mine accidents report (SACMS, 2011). Typical CMM accidents in China include gas explosion, gas outburst, gas ignition and suffocation due to a high gas concentration.

Although it poses a major threat to coal mine safety, methane is also a clean and high-efficiency fuel (Flores, 1998). The energy released in the combustion of 1 m^3 of methane is 35.9 million Joules, equivalent to the combustion of 1.2 kg of standard coal. In the mean time, methane is also an intense greenhouse gas (GHG) with a Global arming Potential (GWP) of 25, i.e. 25 times of the environmental impact over carbon dioxide, in a 100-year span (IPCC, 2007).

Therefore, measures to control CMM in China bear the multiple purposes of promoting mining safety, recovering the methane resource and abating the emission of GHG. Chinese government now plans to use the recovery and utilization of CMM as the core stimulus of CMM control. By spurring methane drainage through increasing the utilization of CMM, the administration expects to promote mining safety and reduce greenhouse methane emissions (Cheng et al., 2011).

This paper gives an analysis of the drainage and utilization of CMM in China by analyzing the methane-involved problems with coal mining and raises a solution of coal–methane co-exploitation model. Projections of future drainage and utilization based on this model are made while China climbs to its coal peak.

Problems with coal mining in China

Low permeability, high gas pressure and gas content of Chinese coal seams are hindering the development of coal mining in China. From the geological view of methane drainage conditions, most of

* Corresponding author. Tel.: +86 516 8388 5948; fax: +86 516 8399 5097.
E-mail address: windfloyd@gmail.com (Y.-P. Cheng).

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China's coal took shape over the Carboniferous–Permian time period. After that the coal went through a number of strong tectonic movements that destroyed the original cracks in coal seams. As a result, the coal became soft, high-ranked, construction-complicated and less smooth for the gas flow. Due to this unique geological condition, CMM in China is characterized by poor drainability, low drainage efficiency, and high maintenance (Cheng et al., 2011). A recent paper by Karacan et al. 2011 gives more detailed analysis for the difficulties of CMM projects in China.

Table 1 lists the permeability of raw coal seams in typical coal mine areas in China, United States and Australia. The permeability of Chinese coal seams is usually in the magnitude of 10^{-4}–10^{-3} mD, except for Jincheng, which is four orders of magnitude lower than the U.S. and three orders of magnitude lower than Australia.

In addition, the deeper level of coal mining also challenges the feasibility, cost and performance of CMM drainage. The shallow coal reserves in China have been exhausted by a fast coal producing rate and Chinese coal mining level is deepening at an annual rate of 10–20 m (NDRC, 2005). The average mining level of Eastern China's mines has reached −720 m. Thirty-two mines have been extended beyond −1000 m. In the case of Huainan and Huaibei coalfields, 85% of the known coal reserve is located at a depth of 800–2000 m underground, and the average mining level reached −850 m by 2009.

Table 1
Comparisons of permeability of raw coal seams in typical coal mine areas in China, United States and Australia.

Coalfield	Permeability (mD)
Huainan	0.00028
Huanibei	0.00121
Tianfu	0.00106
Yangquan	0.00037
Zhengzhou	0.00118
Shenyang	0.00035
Yaojie	0.00244
Jincheng	1.55
San Juan (U.S.)	10–100
Bowen (Australia)	1–10

Several attempts have been made to deal with the problems described above. Technologies such as hydraulic permeability-increasing, enhanced underground boreholes and surface drilling have been successfully applied in some mines. However, wider and further applications are restricted due to complicated process, massive workload and poor drainage performance. It should be noted that lack of knowledge, experience and adequate training of Chinese mining engineers also contribute to the unsuccessful application of the advanced technologies.

A coal–methane co-exploitation model and the applications

A coal–methane co-exploitation model

Chinese known coal reserve is 5.57 trillion metric tons, 63% of which is located at a depth of 800–2000 m. 70% of Chinese coal is featured with multiple-seam existence. There are two kinds of resources in Chinese low-permeability and high-gas-pressure coals seams: coal and methane. If only methane resource is exploited, then low permeability would restrict the methane drainage; and if only coal resource is exploited, the risks involved could lead to gas explosions or outbursts. Furthermore, if methane is not recovered, it is released into the atmosphere thus having a larger climate change impact.

A tentative solution to this dilemma is a coal–methane co-exploitation model. A coal seam with relatively lower gas risks should be selected as an initial mining seam. Through mining this seam, the gas pressure in the adjacent seams (top and below) are relieved and thus permeability increases, facilitating a good condition for high-efficiency methane drainage. Effective methane drainage in the adjacent more gassy seams could turn them into less gassy seams thus realizing the objective of extraction of both coal and methane in a safe environment (Cheng et al., 2009, 2003; Cheng and Yu, 2007; Liu et al., 2009; Yu et al., 2004).

The coal–methane co-exploitation model could solve the gas problems in coal mining, and recover methane, thereby reducing the GHG emissions. It is especially useful in the condition of multiple coal seams, which dominates the existence of coal reserve in China. The model for multiple gassy coal seams is illustrated in Fig. 1.

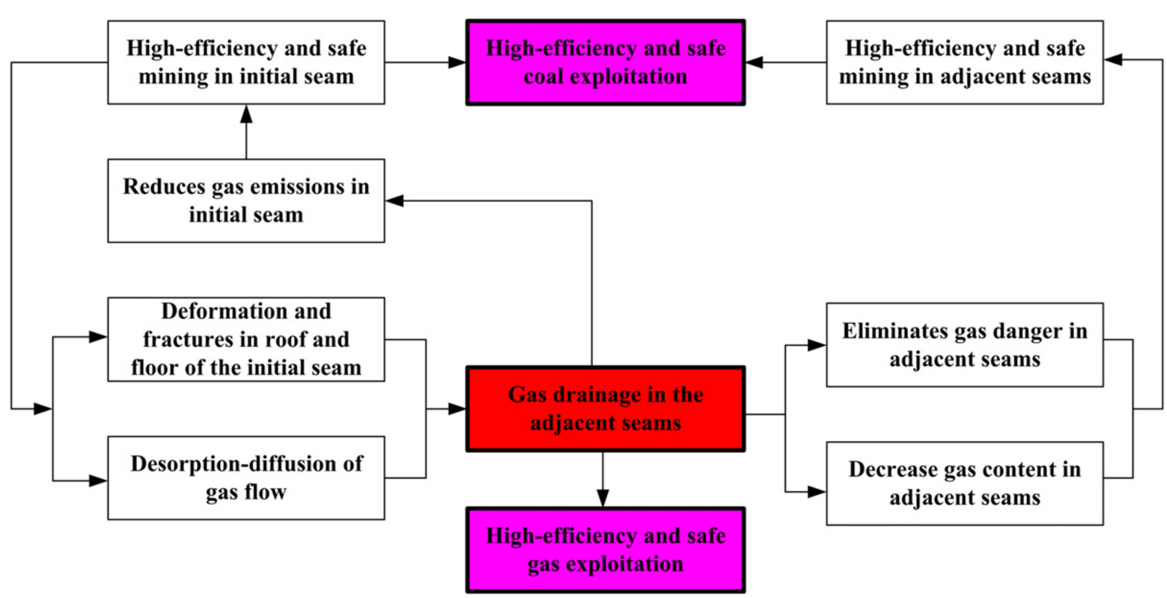

Fig. 1. A coal–methane co-exploitation model for multiple gassy coal seams under the coal–methane co-exploitation model.