International Journal of Rock Mechanics & Mining Sciences 71 (2014) 160–170

Contents lists available at ScienceDirect

International Journal of Rock Mechanics & Mining Sciences

journal homepage: www.elsevier.com/locate/ijrmms

Caving mechanisms of loose top-coal in longwall top-coal caving mining method

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ARTICLE INFO

Article history:
Received 13 January 2013
Received in revised form
18 April 2014
Accepted 25 April 2014

Keywords:
Top-coal caving
The mechanism of the top-coal caving
The top-coal recovery ratio
The marker method

ABSTRACT

The top-coal caving mining method, developed steadily in the past two decades, has become the main method for thick seam coal mining in China. In recent years, the core research areas in the top-coal caving mining are the mechanisms of top-coal caving and the improvement of top-coal recovery ratio. In this paper, the mechanisms of the top-coal caving are illustrated by a large number of physical simulation experiments and numerical modelings of actual cases. The marker method, which has sufficient accuracy to calculate the top-coal recovery ratio, is also described in detail.

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1. Introduction

Coal is the largest energy source in China, accounting for 70% of the primary energy production and consumption. Coal production was 3.5 billion metric tons in 2011, about 50% of the global coal production. In the next few years, production is expected to increase steadily at the rate of 200 million metric tons each year. According to the preliminary estimation, coal production will peak at 4.5 billion metric tons. In China, thick seam mining, referring to those more than 3.5 m thick, is the key to achieving high production and high efficiency coal mining. Currently, both the reserve and production of thick seam coals account for 45% of the underground coal resources and production in China. Therefore, thick seam coal mining plays a very significant role in the performance of Chinese coal industry [1].

Multi-slicing mining, top-coal caving mining, and large-cutting-height mining are the three common methods for extracting the thick coal seams in China. The multi-slicing mining is employed to extract the whole seam from the top to bottom by dividing it into two or more slices. It has the following advantages: less capital investment in equipment is needed, mining technique is relatively matured, and gas control can be easily implemented. However, it also has the following disadvantages: unit production is low, it is very difficult to support the roadways in the lower slices, and the gobs are disturbed repeatedly, making it more liable to spontaneous combustion. The large-cutting-height mining is referred to those longwall panels that extract coal more than 3.5 m thick in one slice. It has been developed rapidly in the past ten years in China. Currently, the maximum cutting height is more than 7 m, the maximum panel width is 400 m, and the maximum shield's yield capacity is 22,000 kN. Monthly coal production is 1.4 million metric tons. The advantages of the large-cutting height are high unit production and high efficiency, while its disadvantages are the use of very heavy equipment and very large capital investment required [2].

The top-coal caving longwall mining is one of the major mining methods for extracting thick coal seams in China. The top-coal caving mining was estimated to have produced about 0.6 billion metric tons every year, accounts for 18% of underground coal mining in China [3]. The major features of the top-coal caving mining are that a conventional longwall mining with cutting height 2–3 m is performed at the bottom of a thick seam, say more than 5 m thick, followed by drawing of the broken top-coal. The top-coal is crushed into fragments under the overburden pressure and drawn through an opening at the rear of the shield support. The broken top-coal is fallen directly on, and removed from the face by, the armored chain conveyor behind (Fig. 1). In order to improve the recovery ratio and enhance gas emissions for the extremely thick (i.e., more than 12 m thick) or very gassy seams, the top-coal caving mining with large-cutting-height has been developed and implemented in recent years. With this method the cutting height can be increased to 3.5–4.5 m, which is good for better ventilation due to the presence of a larger cross-section and a reduction in top-coal thickness.

The fully mechanized top-coal caving longwall mining began in France and Eastern Europe in the 1950s. In 1957, the Kry shield

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http://dx.doi.org/10.1016/j.ijrmms.2014.04.024
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support (Fig. 2a), which had an opening in the canopy, was developed in the former Soviet Union. It was successfully used in Tomusinsk coal mine of the Kuznetsk coal field: In 1963, the “Banana” chock shield support with a lower opening at the rear for the top-coal caving was designed in France (Fig. 2b). It was successfully employed in the Branch coal district in 1964. In the early 1980s, the VHP shield support with only one face conveyor which had an opening at the canopy was developed in Hungary (Fig. 2c). Since then, the top-coal caving longwall mining had been used in Poland, Yugoslavia, and India. The mining height was normally $5\sim10$ m, with some up to 25 m. The average monthly production per panel was between 10,000 and 30,000 metric tons. The highest monthly production was in the Branch coal district in France, with about 49,600 metric tons. Overall, the results of the top-coal caving mining were less than desirable back then, because it was mainly used for mining the corner blocks of coals. Due to change in the international energy development, the application of top-coal caving longwall mining began to decline in the 1980s. In the 1990s, only a few coal mines employed the technique, and today no coal mines in the world outside of China use it [4].

In China, the top-coal caving longwall mining began in the 1980s. The Chinese made FY4000/14/28 shield supports for the top-coal caving mining were installed on trials in Puhe mine in Shenyang in June 1984. Due to its low strength, the shield's four-bar linkages were severely damaged. In adddition, the shield could not be moved forward due to lack of compatibility. The panel eventually caught fire and the shield trial was aborted. In 1987, the #1 coal mine of the Pingdingshan Mining Bureau imported the VHP-732 plug-bottom shield support with high drawing opening from Hungary. Their application was fairly successful with an average monthly production of 44,206 metric tons, a coal recovery rate of 79.6%, and an average productivity of 25.5 t/hr. The top-coal caving longwall mining was successfully put on trials in Yangquan Mining Bureau in 1988 and Lu'an Mining Bureau in 1989. At the same time, research on the top-coal caving mining in steeply inclined thick coal seams began with good results [5].

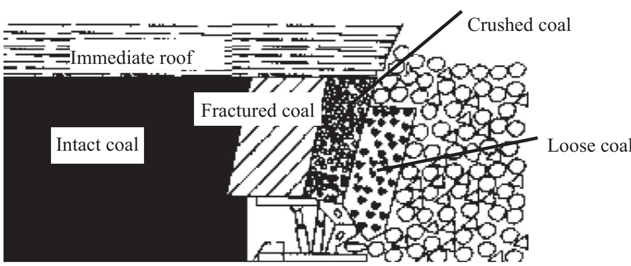

Fig. 1. Schematic highlighting the top-coal movement in top-coal caving mining.

Today, the top-coal caving longwall mining is the major mining method for thick seam coal mining in China. In the Datong coal district, the annual production is 1.5 million metric tons per panel. The top-coal caving longwall mining has attained outstanding achievements in coal mines with favorable conditions. It has also achieved significant results in the following three geological condtions: three softs (soft roof, soft floor and soft coal)“, “Two hard (hard roof and hard coal)“, and “unstable“ coal seams.

There are three issues in using the top-coal caving mining method: The first is to increase the top-coal recovery. The second is the methane control. And the third is fire control in gateroad and gob. Among these three issues, the top-coal recovery rate is the core and special issue [6].

Knowing, studying and utilizing the caving mechanisms and drawing of the loose top-coal are the key to increase the reovery rate of top-coal [7,8]. The top-coal caving is built on the top-coal drawing. In the earlier studies, the ellipsoid drawing theory used in hard rock mining was employed to determine the parameters of top-coal caving. Those parameters were adjusted when applied to individual cases of top-coal caving mining by employing the physical simulation experiments and numerical modelings. However, in the course of study, especially in the physical simulation experiments, the influnce of the tail canopy and cyclic advance of shield were not considered. So the results from utililizing the elllipsoid drawing theory were not realistic. This paper has performed a large number of physical simulation experiments and numerical modeling fully considering the effects of tail canopy

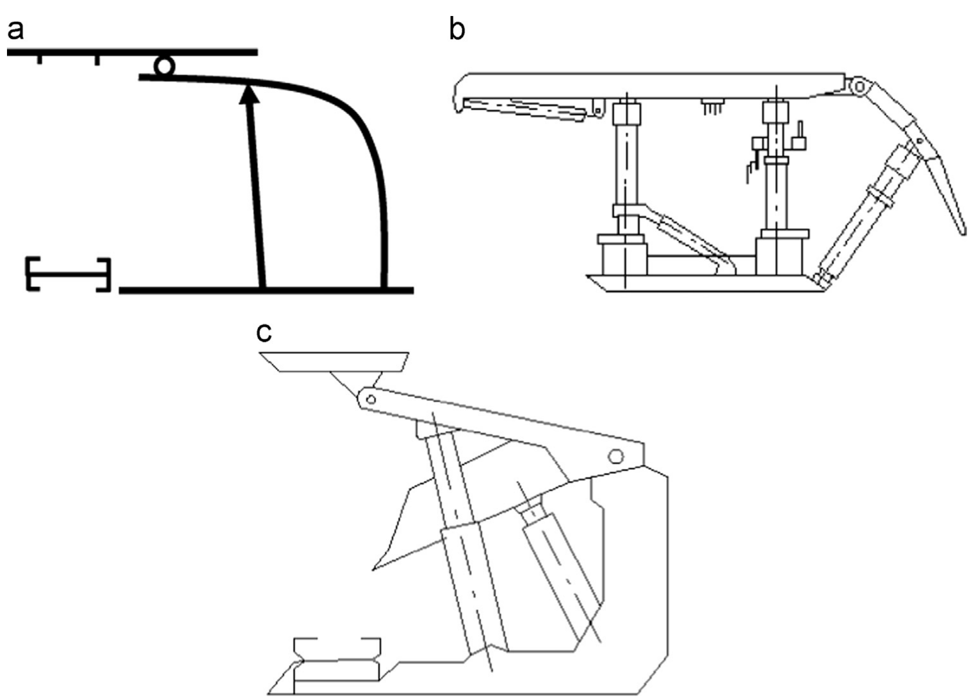

Fig. 2. Various top-coal caving shield supports used in Russia and Europe. (a) The Kry top-coal shield support. (b) The “Banana” top-coal shield support by France. (c) The VHP top-coal shield support with only one face conveyor.

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