Mining Safety of Longwall Top-coal Caving in China

Jian Wu,[1] Yueping Qin,[1] and Minghua Zhai[2]
[1]China Univ. of Mining and Technology, D11# Xueyuan Road, Haidian Dist, Beijing 100083, P. R. of China;
[2]Zhangji Coal Mine, Xuzhou Mining Bureau, Xuzhou 221147, Jiangsu Province, P.R. of China

ABSTRACT

Longwall top-coal caving technology has developed rapidly in China, in recent years. The application of longwall top-coal caving can double both the productivity and the efficiency of a working face and reduce the cost of production by 30 to 40%. Using standard longwall equipment, annual production can reach 3 million metric tons (Mt), and a maximum of 4.1 Mt has been obtained; many top-coal caving longwall working faces can obtain 200 tons per man-shift.

Longwall top-coal caving is distinctly different from slice mining in thicken seam. Concerns of safety and productivity for this method have been raised in recent years. This paper will discuss the following: 1) how to recognize the law of fire-damp emission, accumulation and outburst; 2) how to resolve the ventilation problem in a highly gassy working face; 3) how to recognize the law of spontaneous combustion of ignitable coal, and to avoid spontaneous combustion in gob area; and 4) How to control dust in longwall top-coal caving face.

KEYWORDS

Longwall Top-Coal Caving, Thick Coal Seam, Mine Safety, Gas Emission And Outburst, Spontaneous Combustion, and Dust Control.

INTRODUCTION

In China there is an abundance of thick coal seams. These account for about 45% of the total national coal reserve. In recent years, about 44% of coal production come from these thick seams. Several years ago, thick seams were mostly mined with a longwall slicing method which presented many safety. When the first slice is mined, a large amount of gas is emitted and flows from the following slices to working face. As a result, the specific methane emission is often doubled and gas control becomes more difficult. This slows down face advance speed and restricts coal production.

When a seam is mined repeatedly, it provides a favorable condition for spontaneous combustion of residual coal in goaf. When a thick seam is mined with a longwall slicing method, spontaneous combustion occurs frequently and thick coal seams become unminable. However, experiences in the filed has shown that longwall top-coal caving (LTC) method can solve the above mentioned safety problem using longwall slicing and still remains highly productive.

In 1982, China introduced its first LTC method. Although the first test face (Puhe Coal-mine of Shenyang Mining Bureau in 1984) was not successful, it has subsequently been applied successfully in steeply inclined thick seam in Meihekou Coal-mine of Liaoyuan Mining Bureau and Liudaowan Coal-mine of Urumchi Mining Bureau. In 1990, LTC was successfully tested in a flat-pitching seam at Luan Mining Bureau and Yangquan Mining Bureau, achieving 140,000 mt in a single month. Since then LTC was adopted in many mines in China. Today, the production of a LTC working face under favorable geological conditions exceeds 2 Mt annually. For instance, in Yanzhou Mining Bureau's Dongtan Coal-mine, its LTC face produced 4.Mt coal in one year, with per man-shift at 208 tones. Now, LTC can also be applied in many difficult mining conditions: thick seams with soft roof and floor, tight roof and seam, high slope angle, large gas content (even with potential for gas outburst), susceptibility to spontaneous combustion, or even with thin coal seams.

Because LTC is very different from longwall slicing method, so are some of the challenges during a mine disaster and many safety problems must be resolved. What's the characteristic of gas mission and gas outburst in LTC comparing with longwall slicing? Can LTC be used to mine seams with large gas content or liable to gas outburst? What's the difference in spontaneous combustion between LTC and longwall slicing? How could spontaneous combustion be prevented in LTC working face? What measures should be taken to control coal dust in LTC working face? In this paper, authors will review the practice of mine disaster prevention of LTC in China.

CHARACTERISTICS AND PREVENTIVE MEASURES OF GAS EMISSION AND OUTBURST

Characteristics of Gas Emission in LTC Working Face

The LTC system mines the entire coal seam in one pass. Its gas emission characteristic are different from longwall slicing method as follows:

The specific methane emission is less. In longwall slicing method, when the top slice is mined, gas in following slices enter into working face. The working face in the first slice has the largest gas emission, becomes less in following slices. Table 1 shows data from the Luling Coalmine of Huaibei Mining Bureau. This thick seam is mined in 4 slices, about 60% of gas is discharged during the first slice.

In the LTC method, the overall thickness of seam is mined once, so that the specific gas emission is even and much less than that of first slice working face, because the speed of the face advancing is slowed down.

Table 1. Gas emission proportion in each slice.

Number of slice	1	2	3	4
Gas emission proportion / %	43-75	12-24	9-17	8-16

The absolute methane emission is also increased because of two reasons. First, the production of LTC working face is 2~5 times as that of slicing working face. Second, the LTC method mines the entire seam in one pass so that decompression area becomes greater, height of cracked zone is increased, and more gas in adjacent seams may gush into working face.

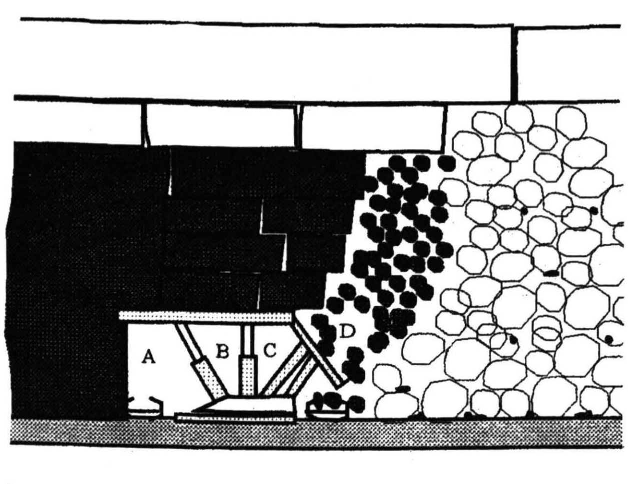

Figure 1. Methane distribution in face

There are more methane accumulation spots. Methane accumulation occurs not only at the upper (or bottom) corner of the face like in slicing working face, but also around caving orifice and above support canopy. Figure 1 shows explosive gas near the working face is in zone D.

Gas emission is uneven during the mining operation. There are methane in high concentrations above the support, it flows out during the caving process or support movement, so the methane concentration varies following the mining process. The factor of gas emission varies is between 1.2 and 1.4, some times even over 2.0.

Methane distribution in the face area is uneven, too. As shown in Figure 1, the mining face can be divided into three parts: A, B and C. In zone A, the rate of airflow is the greatest, with about 70% of the air quantity passing through, resulting in the lowest methane concentration. In zone C, the space is smaller and ventilation resistance is high, and only less than 10% of the air quantity pass through. Methane emission from goaf and caving coal come into it, so that the methane concentration in zone C becomes higher than zone A and B. The wetland concentration in zone B will be between zones A and C. Zone D does not belong to working face, but it is in the area above the caving orifice. In zone D, gas concentration may be in an explosive region. It flows with caved coal into face space and increases methane concentration in the working area.

GAS OUTBURST IN LTC WORKING FACE

Factors that affect Gas Outburst

Generally, a soft coal seam will be more susceptible to methane outburst. With the slicing method, tow pick headings are disposed in the floor and connected to haulage entry with oblique headings. To drive oblique heading needs to uncover the seam and thus increases the possibility of gas outburst. For instance, in Luling Coal, there have been 19 gas outbursts in history, 17 of them took place while the seam was being uncovered by driving oblique headings.

In LTC method, pick headings are not needed. There are no oblique headings, and gas outbursts caused by uncovering seam can be removed. When using LTC method, there is a greatly concentrated stress area will form in coal seam immediately ahead of the face, and peak abutment moves farther away from face. The cracked zone in coal seam ahead of the face expands, which make the gas release easier and gas pressure gradient lower. Therefor, LTC tends to inhibit gas outburst. In several mines, LTC has been successfully used to mine the thick seams that are susceptible to outburst, after gas drainage.

However, since the air intake road and air return road are located at the bottom of coal seam in a LTC system. The gravitation of coal above the road enhances the possibility of gas outburst.

METHANE EXPLOSION PREVENTION MEASURES

Gas Drainage

Gas drainage is an essential method to prevent a methane explosion. It discharges the methane and thus reduces gas pressure. Gas drainage methods can be divided into three kinds: predrainage, gas drainage during mining, and gob gas drainage. All drainage methods used in slicing method can also be used in LTC. For the three methods, it has been proven that drainage during mining is more efficient in a LTC face than in slicing face. The cracked zone ahead of the LTC working face is greater, which make the gas drainage easier. In some mines, most gas emission comes from adjacent supper seams.

There is a method that can efficiently reduce the gas emission from adjacent upper seams. As shown in Figure 2, this method is to drive a heading (along seam strike or dip direction) or drill a large-diameter hole in roof strata. Gas is drained out from the heading or through the hole.

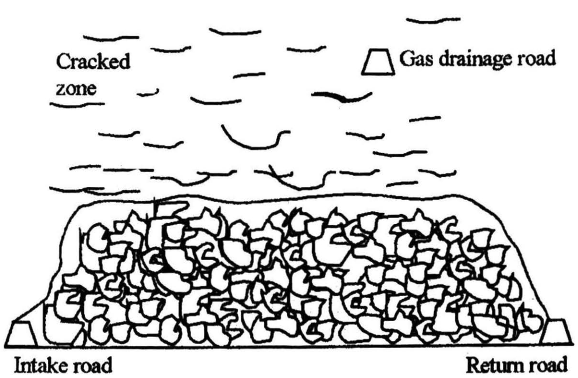

Figure 2. Gas drainage road along the seam intake.

Mining the Protective Seam

In regions where not all seams are gassy, then the seams without the possibility of gas outburst is mined first, this will de-stress the seam, thus facilitates methane drainage to reduce the possibility of gas outburst. This method has been used in China since 1958, and has been proven as an efficient and economic method to prevent gas outburst. However, there are areas where all seams are gassy or this "protective" seam may be so thin that it is not economically minable. This method is rarely applied on a LTC working face.

In some mines, there is only one thick seam with large methane content. In order that LTC is safely used, the top slice of seam is still mined with longwall slicing method. The drawback is that the top slice face can't work regularly, resulting in reduced production which affects the regular production of LTC face.

Modification of Ventilation System

In U form of ventilation system, in order to reduce the methane concentration in return air to below the allowable value (1%), the air quantity of face is estimated as:
where Q= air quantity of face, m^3/min; K = gas emission

$$Q = \frac{K \cdot Q_0}{C} = \frac{K \cdot q_0 \cdot A}{1440\ C} \quad (1)$$

uneven factor; Q_0 = mean absolute gas emission, m^3/min; C = allowable methane concentration in air, %; q_0 = mean specific gas emission, m^3/t; A = mean productivity of face, t/day.

The air quantity is restricted by the maximum of airflow 4 m/s. If the cross section of roadway equals to 6m^2, the maximum air quantity is 1,440 m^3/min, which requires that the absolute gas emission be less than 10.3 m^3/min, and specific gas emission be 10 m^3/t, giving a maximum production face 1481 t/day. In order to maximize the high productivity in a TLC system, proper measures for efficient gas drainage and ventilation system be taken.

Since 1992, E form ventilation system (Figure 3) has been used in many mines. This system is formed by increasing a gas drain based on the U form system. The gas drain is a heading located at the top of the coal seam. The horizontal interval between it and return airway is 10~20 m. There is no person and any kind of equipment in it. It is over the face and the air in it comes from the air leakage in goaf and broken coal above the powered support with high concentration of methane. The methane concentration in the gas drain should be no more than 3%, which has been operating satisfactory up to present. The purpose for this system is to control methane concentration at the upper corner of face.

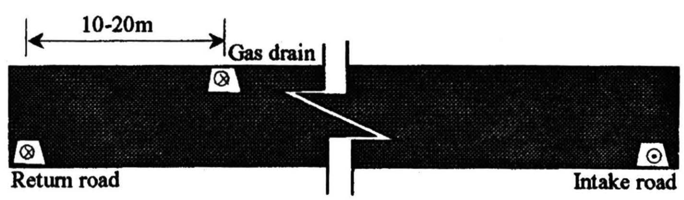

Figure 3. The E form ventilation system.

SPONTANEOUS COMBUSTION PREVENTION MEASURES

Spontaneous Combustion in LTC

The LTC system has a much higher production and thus takes a shorter mining period seam than the slicing system. After mining, the goaf can be closed in time. The spontaneous combustion is a slow process of oxidation and accumulation of heat. For example, in third mine of Yangquan Mining Bureau, the No. 15 seam was mined with slicing system with 3 slices. The shortest period from mining the first slice to combustion is 24 months (incubation period). It takes 40~50 months for all 3 slices to be mined out. There have been 17 cases of spontaneous combustion in slicing system. With the LTC system, it takes only 13 months to mine the same full thickness in a face. The goaf is sealed in 15 months, so that the possibility of spontaneous ignition is greatly reduced.

The LTC system reduces the air leakage, which is the major cause of spontaneous combustion. In the longwall slicing system, 90% of the spontaneous combustion takes place in the lower slices. After the first slice is mined, the rock in goaf is bulky. The air can pass through goaf from the oblique headings connected with intake air pick heading to the oblique headings connected with return air pick heading. After coal roads of lower slice are driven, the air can be leaked from intake entry to return entry through goaf. The goaf of upper slice is oxidized for a long time, the spontaneous ignition may take place in the front and rear areas of the lower slice face. In the LTC system, there are no pick or oblique headings. There is no such leakage in the slicing system, and the possibility of spontaneous combustion is reduced.

It is easier to seal the goaf in LTC system. In the slicing system, pillars around rise or dip is acted by concentration stress repeatedly. There are more cracks in pillars, which make it difficult to seal the goaf. A great amount of spontaneous combustion is caused as the air leaks through pillars. In a LTC system, the pillars are affected by concentration stress only once, pillars keep their integrity and goaf can be sealed tightly. Hence, there is less spontaneous combustion in pillars and goaf.

However, in LTC system, coal headings are located along the bottom of the seam, the possibility of roof-fall and rib fall is increased. There are air leakage in roof-fall spot and cracks around roads, which makes the spontaneous combustion in coal seam around road or in goaf as the coal with high temperature left behind face possible.

The recovery rate of coal is lower in the LTC system, and the loose coal in goaf may induce spontaneous combustion as well.

It is also possible that the 8~10 m top-coal in the region between the start line and stop mining line along advancing direction is not entirely caved down, and it will be left in goaf. It is easy to induce a spontaneous combustion if the goaf could not be sealed tightly.

Spontaneous Combustion Prevention Measures

Experience in the field has shown that the following measures are effective in preventing spontaneous combustion:

To Increase Face Advance Rate

The goaf can be divided into 3 zones according to the stages of spontaneous combustion: cooling zone, oxidation zone and asphyxia zone. The larger the oxidation zone is, the longer it will be for coal to oxidize and heat to accumulate, thus increasing the likelihood of a spontaneous combustion. Increasing the face advancing rate makes the oxidation zone smaller and reduces the possibility of spontaneous combustion.

To Inject Nitrogen into Goaf. Nitrogen with over 99% purity is injected into the goaf through the pipe buried beforehand in goaf along the intake airway.

To Use Oxidation Retarding Agent. In China the agents generally used are $MaCl_2$, $CaCl_2$ and soluble glass.

To Inject the Mud Slurry. To inject the mud slurry is a common and efficient technique to prevent spontaneous combustion in China.

To Reinforce the Coal around the Coal Roadway. Filling the gap between the roadway support and the coal wall reduces the air leakage in the surrounding coal.

Fireproof and Extinguishing by Balancing Pressure. Decreasing the air pressure difference around the goaf can prevent the air leakage in goaf, and to prevent spontaneous combustion.

DUST CONTROL TECHNIQUE

In China, the dust concentration exposed by worker is restricted by the national standard, but the safety rules and regulations do not forbid that workers to stay in the return air. The LTC system is another dust source, because caving process produces dust. The dust concentration in LTC working face is higher than regular longwall working face, so the LTC system requires more stringent practice to control dust. In China the following measures have been used to control dust.

- Instead of high caving gate supports, the low caving gate supports are widely used .
- Dust control by water-cloud should be enhanced. Sprayers beneath the forward canopy are installed to contain the dust produced by shearer drum. Sprinklers are installed on the gob shield, which automatically spray while moving support or caving top-coal. Sometimes the wetting agent is dissolved in water to increase the effect of dust control.
- Preliminary infusion in seam is widely used in China.
- The new dust arresting devices are being researched.

EPILOGUE

The LTC system has been developed rapidly in China in recent 15 years. The research of safety measures of a LTC system has obtained some achievements. The characteristics of safety problem in a LTC system has been basically identified. Many efficient measures are taken to prevent methane explosions, spontaneous combustion and dust. In this past 15 years, there have not been any serious accidents that have taken place in any LTC system in China.