Research situation and prospect of fully mechanized mining technology in thick coal seams in China

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Abstract

Coal production in China accounts for 1/3 of total output in the world, and nearly half of China’s output is extracted in thick coal seams. Therefore, it is significant to study fully mechanized mining technology in thick coal seams. The development, current situation, and issue of slicing mining, top-coal caving, and coal seams cutting sufficient height with fully mechanized mining technology are systematically analyzed in this paper. According to result of analysis, the prospect of development of fully mechanized mining technology in thick coal seams is discussed. Especially, authors have represented the key problems which block the development of fully mechanized mining technology in thick coal seams.

Keywords: thick coal seam; fully mechanized mining; current situation and issue

1. Introduction

The coal reserve and production extracted from thick coal seams account for 40\%-60\% \cite{1} of national coal resource/production in China, respectively. In 2008, the production of coal was 2.716 billion tons, accounting for more than 1/3 of the total coal output in the world. This situation means that, in China, the thick coal seam mining technology has been advanced in the coal mining field of world. Fully mechanized mining technology has been applied in 77.47\% of the state owned key coal companies in 2006, and the mortality rate is 0.628 \cite{2} in one million tons of coal exploited. Because of the limitation of geological condition, technology, and cost of mining, three major mining methods have been used for thick coal seam exploitation, which are slicing mining, top-coal caving, and the technology of cutting sufficient height with fully mechanized mining. According to result of analysis, the prospect of development of fully mechanized mining technology in thick coal seams will be discussed in this paper. Especially, authors will represent the key problems which block the development of fully mechanized mining technology in thick coal seams.

2. Slicing mining method with fully mechanized mining technology

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Since the slicing fully mechanized mining technology has gotten a successful testing in Tangshan mine of Kailuan colliery in 1974, this technology has been popularized to 77 mining areas such as Kailuan, Yanzhou, and Xingtai, etc. The advantages of this technology are higher extraction ratio, lower speed of subsidence of overburden, and better safety condition of mining. However, the disadvantages are higher gateways excavation ratio, higher cost of support and maintenance of gateways, lower production of working panel and complicated production management. Due to such disadvantages of slicing mining method, at present, most of coal mines with gentle dip of thick coal seam have employed top-coal caving and cutting sufficient height with fully mechanized mining technology in China. The slicing mining method is still used in conditions of extra thickness of coal seam or special condition that is limited to use other mining methods.

3. Present development of top-coal caving with fully mechanized mining technology

3.1. Development of top-coal caving mining technology

Top-coal caving with fully mechanized mining technology started from Europe in 1960s, and was mainly used for mining boundary pillars. This technology has been developed in three stages, which are exploration stages (1982~1990), development stage (1990~1995), and maturity stage (1996-now) [3]. The position of caving has experienced from the high site, middle site and low site in shields in thick coal seams. The roof support system of shield has changed from four leg shield to two leg caliper shield. This technology has gained great achievements in China. It is shown that top-coal caving with fully mechanized mining technology has developed quickly since 2002 in Fig. 1. In 2002 the productivity of longwall working face of Xinglongzhuang coal mine has achieved 6,400,000 tons per year in conditions of using ZFS6800/18/35 shield, SL300 cutting machine produced in German and matching convey system. During recent three years, the production of longwall is about 8,000,000 tons per year at least when using top-coal caving with fully mechanized mining technology. The production of longwall working face have been up to 10,330,000 tons per year, 49,200 tons per day and 1,068,700 tons per month at most respectively in Anjialing #2 coal mine of Pingsuo colliery when the mining equipments of ZFS8000/23/37 shield and MGTY400/930-3.3D cutting machine were employed in the working panel. These data shows this technology has several advantages such as higher productivity, lower gateway excavation ratio, lower cost of production and higher flexibility. Therefore, this technology has been used widely in thick coal seams in China. At present, this technology has been introduced to Australia, Vietnam and other countries.

Fig. 1. The production per working face using top-coal caving with fully mechanized mining technology (recording from 1994 to 2008)

3.2. Research progress about top-coal caving with fully mechanized mining technology in special conditions

The top-coal caving with fully mechanized mining technology has been successfully applied in conditions of “three soft” coal seams, coal seam methane with high level, steeply dipping coal seams, “two hard” coal seam, shallow coal seams, and/or thinner coal seams. The practices show that the excellent effect has been obtained. For example, working face #5120 using top-coal caving mining method has produced average 79,000 tons per month, 130,000 tons at most in one month in Wuyang mine of Lu’an Coal Group, and the extraction ratio was 85.7%. The #1 mine of Yangquan Group has achieved 400,000 tons in one month at most in conditions of high level methane of coal seam. Dongtan coal mine has reached average 498,400 tons per month, and 556,000 tons in one month at most,
respectively. In Anjialing #2 mine of Pingshuo Group has attained average 18,300 tons per day, and 24,500 tons in one day at most in conditions of shallow burial and “two hard” coal seam. Qishan mine #3121 longwall panel using top coal caving with fully mechanized mining technology has achieved the average monthly output 65,000 tons, and extraction ratio was 94%.

The light shield with fully mechanized top-coal caving technology has been widely applied in some working faces in conditions of smaller productivity, small region of continuous mining panel, irregular panel and steeply dipping coal seam. For instance, after Shigejie mine has applied light shields with fully mechanized top-coal caving technology into the exploration of irregular coal pillars, the average monthly production is about 95,000 tons. In Kailuan colliery, total production is around 3,000,000 tons in 15 working faces when this technology has been employed in conditions of steep dipping, high stress, broken roof, and/or pressure water etc.

3.3. Main achievements of mining safety when using top-coal caving with full mechanized mining technology

The mining safety issues when using top-coal caving with fully mechanized mining technology have been systematically researched. Especially, the control techniques of coal seam methane and spontaneous combustion in coal seams have gotten a significant progress recently. For example, the traditional U-shape ventilation has been replaced by E-shape and Y-shape ventilation, which can enhance capacity of ventilation of working panels when using top-coal caving with fully mechanized mining technology. Hydraulic slotting equipment and technology have been developed, which improves the coal seam permeability. The three-phase foam fire extinguishing technology and colloid extinguishing technology have been developed, which can retard spontaneous combustion in coal seams.

3.4. Main technical issue of top-coal caving with fully mechanized mining technology

(1) Because coal extraction ratio is relatively small and about 80% when using top-coal caving with fully mechanize mining technology, It is a major problem that how to improve extraction ratio at present.

(2) The current problem is how to soften the hard top-coal. At present, it is not apparent to improve the effectiveness of soften top-coal after using some measures such as high-pressure water injection in coal seams, deep-hole blasting and so on. Therefore, further study should be done to research the fracture expand mechanics affected by hard coal, water pressure and corresponding monitoring technology.

4. Current development of cutting sufficient height with fully mechanized mining technology

Since the cutting sufficient height equipments have been introduced to China in 1978, the cutting sufficient height with fully mechanized mining technology has been researched. The first industrial testing homemade mining equipments have begun from 1984 in #18202 working face of Guandi coal mine of Xishan mining group. Due to the limitation of cutting equipment capacity, poor adaptability of shield equipments and incomprehensive adjoining rock behavior, the production of working panel was less than 2,500,000 tons per year, which is shown as in Fig. 2. After 1998, the cutting sufficient height with fully mechanized mining technology has developed rapidly, and especially this technology successfully used in Shendong colliery. Therefore, the production of working panel has increased widely. After Da Liuta mine adopted 6LS5 cutting machine produced by JOY Company, WS1.7 shields produced by DBT Company and the entire set of import equipments in 2002, the production of signal working panel was up to 8,034,000 tons per year. In 2003, the highest production of signal working panel was more than 10,000,000 tons per year, which have reached the international advanced standard. In 2006, after #2307 working face of Sihe mine in Jincheng, firstly adopting ZY9400/28/62 homemade hydraulic shields and the SL-500 cutting machine made in Germany Eickhoff Company, has sufficiently extracted the coal seam with thickness of 6.2 m, the average monthly production was 660,000 tons and the highest monthly output was 780,000 tons. During recent three years, the highest production using cutting sufficient height with fully mechanized mining technology has been more than 11,000,000 tons per year. In 2008, after Bulianta mine have adopted the SL-1000 cutting machine produced by Germany Eickhoff Company and homemade ZY10800/28/63D shields, the production of working panel has been up to 11,800,000 tons per year. In Wanli #1 mine, the production was up to 10,150,000 tons per year with the homemade equipments of ZY8600/24/50D shields and MG750/1815-GWD cutting machine.
Practice shows that cutting sufficient height with fully mechanized mining technology has advantages of high production, high extraction ratio, be easy to control methane and spontaneous combustion in thick coal seams according to compare with slicing mining method. The cutting sufficient height with fully mechanized mining technology has become a new mining method with vast development potential, and is developing a new field of mining research. At present, Sijiazhuang mine of Yangquan colliery is studying how to enhance the mining safety in conditions of high absorption gas, extra-soft coal in the upper part of coal seam when the cutting sufficient height with fully mechanized mining technology were used. Xutuan mine of Huaibei colliery is study how to coordinate mining equipment and mining method in conditions of high absorption methane, “three soft” and geological bifurcation, so these research have extended range of using this technology.

The cutting sufficient height with fully mechanized mining technology is the main development direction of fully mechanized mining in thick coal seam. At present, the main technical problems are affecting the cutting sufficient height with fully mechanized mining technology as follows.

(1) The coal rib fallen control in cutting sufficient height with fully mechanized mining technology is a challenge problem. The serious coal rib fallen is affecting seriously the mining safety when using this technology. Statistical data shows that the number of fallen rock accidents when using this technology is several times more than traditional fully mechanized mining face.

(2) The equipment stability control in cutting sufficient height with fully mechanized mining is also main problem. The equipments has higher gravity center and poor stability, especially in conditions of steeply dipping coal seam, broken roof and floor with soft coal seam, the preceding disadvantages would be more serious. Thus, the key problem is how to stabilize the mining equipments in such geological conditions.

5. The development prospect of fully mechanized mining technology in thick coal seams

Although China’s thick coal seam’s fully mechanized mining technology has made considerable progress, comparing with the advanced coal mining countries, it still has weaknesses such as low coefficient of resource recovery, low work efficiency, lagging manufacturing industries of mining equipments and so on. Thus, further studies should be done on China’s thick coal seam’s fully mechanized mining technology from the following aspects.

5.1. Research on how to increase coal recovery coefficient when using top-coal caving with fully mechanized mining technology

(1) The loss of pillar between two sections is an important component of total coal loss in thick coal seam. Therefore, it is necessary to do further research about gob-side gateway driving and gob-side gateway retaining to reduce the section coal pillar loss and increase resource recovery coefficient when using top-coal caving with fully mechanized mining technology.

(2) Improving coal mining technology and doing a further research about reasonable mining-caving ratio, interval of caving, caving-mining process, automatically identifying and corresponding controlling technology for caving, and how to reduce coal loss in head and tail of longwall face.
(3) Researching on mining technology and complete sets of equipment in cutting sufficient height and top-coal caving, especially in thick coal seams with thickness of more than 14 m, to increase the mining overall height at one times and coal recovery coefficient of fully mechanized mining. “Coal Mine Safety Regulations” requires that the mining-caving coefficient is not less than 1:3. In order to solve this problem, it is necessary to do further research about cutting coefficient height with fully mechanized mining technology and top-coal caving in slicing layers.

5.2. Stability of mining equipments and strata control technology using cutting sufficient height fully mechanized mining technology

The coal mining equipments matching and strata control are the crucial issues of cutting sufficient height with fully mechanized mining technology. In order to solve these problems, further researches should be done as follows.

(1) Research the characteristics of overlying strata’s breaking and mechanics of structural stability, including the characteristics of roof broken in conditions of different mining methods (mining along the strike, uphill mining, and downhill mining) and the mechanics of roof broken in conditions of different cutting heights, “three zones” distribution range and distribution, the law of abutment pressure with mining, overlying strata’s structural stability principle and control technology.

(2) Research on the coupling relationship between working face support and surrounding-rock, including working face rib spalling, roof falling mechanism and its corresponding control, support stability principle and its control, support surrounding-rock coupling mechanism.

5.3. Research about automatic fully mechanized mining technology

Automatically mining with fewer or no person is a hot issue in current international mining research [4]. It is relative late for the development of thick coal seam automatic fully mechanized technology research in China. In 2004, Shendong Mine and Halagou Mine of Shenhua Group have successfully carried out testing working faces #45204 and #02203 respectively with automatic fully mechanized mining technology, which cut in half-depth of cutting drum. Working face #31306 has run two-way automatically cutting in Bu Lian-ta mine with thick of coal seam in 2004. The production of these automatically working faces was more than 900,000 tons per month. In March, 2007, the first automatic fully mechanized working face that produced 6,000,000 tons per year with independent intellectual property rights has been operated smoothly in Dongtan mine of Yankuang Group. The testing automatic working face in thick coal seam #6203 has obtained 633,000 tons per month at most during the period of industrial test in Wangzhuang mine of Lu’an Group. Due to the influence of complex geological condition and all kinds of other unknown factors, automatic fully mechanized mining technology is relative unadvanced. In order to change this situation, some key technologies should be solved as follows.

(1) Automatic location of cutting machine and automatic adjustment of height of cutting drum. This kind of research include dynamic model of cutting machine, precisely locating position of moving target and calculating corresponding speed, error compensation model of trail of cutting machine and its adaptability in all kind of conditions and establishment of guide mine map-matching (MM) algorithm. Further research on combined height-adjusting technical method should be done, which includes intelligent coal-rock detection and its corresponding control system, radar detection technology, etc.

(2) The automatic recognition system of interface of coal and rock, and corresponding automatic top-coal caving technology. It is necessary to invent a kind of sensor that can indentify coal and rock with certain resolution.

(3) Production information automatic acquisition system in longwall working face. It includes the automatic acquisition, analysis and feedback of mine pressure, equipment operating condition, etc.

(4) Full duplex communication technology between underground and ground, including information transfer technology, multi-sensor coupling technology, database technology, development of related software, etc.

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