Safe Effective Key Mining Technologies of Fully Mechanized Caving Face in Steeply Dipping Seam

Xiao-meng Li[1,a], Zhan-bo Cheng[1,b]

[1]School of Resource and Safety Engineering, China University of Mining and Technology (Beijing),Beijing 100083, China

[a]jack100121@126.com, [b]chengzhanbo0825@163.com

Keywords: steeply inclined thick seam, zone controlling of surrounding rock, equipment stability, optimizing of drawing technologies

Abstract. Floor failure and slipping, rib spalling, toppling and slanting of supports and gliding of equipment in the panel generally exist during the top coal caving of steeply inclined thick seam. Technologies of fast moving, zone controlling of surrounding rock and equipment's stability controlling were put forward through theoretical analysis and field practice. Drawing technologies were also optimized. It shows that key technical problems that limits the production and safe effective mining are solved after applying the key technologies above. Meanwhile, the paper can provide references for the mining of coal seam with similar geological conditions and in the lower level.

Introduction

As the superior coal seam becomes less and less, mining steeply dipping seam gets more important than ever before. The steep seam mainly exists in the south and northwest of China, such as Sichuan, Guizhou, Xinjiang and Anhui. Though many performances have been achieved in the steeply dipping seam in the past decades, many problems still exists. Lower rate of top-coal recovery, rib spalling, complicated mining technologies and poor stability of equipment lead the slower advancing speed and lower production. Many experts have researched these fields including the equipment stability, rules of strata movement, rib spalling and floor slipping. However, specific measurements about panel moving, drawing technologies, controlling of surrounding rock and equipment's stability were rarely studied. These actions are necessary for reaching the safe and effective production and have significant meanings.

Geological Condition

#2 coal seam is the major seam of Panel 1201 in Dayuan coal mine. Its average thickness is 6.8m, including 2.3-meter mining height and 4.5-meter drawing height. Its average dip angle is 53 degree. The coal seam is very soft. Its Protodyakonov coefficient is from 0.1 to 0.15.The direct roof is mudstone with about 0.75m. Its Protodyakonov coefficient is from 0.1 to 0. 5. The basic roof is siltstone with 8-meter thickness. The direct floor with 4-meter thickness is also soft siltstone. The designed production of this coal mine is 1.2 million tons per year. But complicated geological condition caused a series of technical problems and limited the increase of production. The suspending roof in the upper end during first mining was particularly difficult to handle, which seriously threatened the safety in production. Besides, softer coal seam and floor could easily lead rib spalling and failure slipping of floor and triggered local roof fall and the instability of "roof-support-floor" system. Furthermore, smaller load of supports could intensify the toppling and slanting of supports. The roof can't be supported effectively, which lead the accidents of rib spalling and roof fall. Larger dip angle results in the slipping of scraper conveyer, support and coal cutter, which heavily affect the normal production. The paper studied the key technical problems of installing and withdrawing of equipment, stability controlling of surrounding rock and equipment as well as the optimizing of drawing technologies. It solved the relevant technical problems that restricting the safe and effective production of coal mine.

Transporting, Installing and Withdrawing of Equipment

Equipment transportation. The former ends of basic and transitional support are fixed with flat car by two bolts of M36mm×350mm. The rear end is fixed with the flat car by two bolts of M36mm×150mm. When transporting with flat car, the dedicated safe joint pin must be adopted. The former beam is in front and tail beam on the behind when transporting. When transporting down along the cutting hole, make the tail beam ahead and former beam downward.

Installing of equipment. Installing is going on as transporting and unloading. Installing work can start when partial equipment is in place. Set positioning line and initial place before installation. And adjust central line and direction. The switches were firstly transported. Then install all the winches and set electric wire ready and power on. Transport and install the scraper conveyer, coal-cutter and supports in turn. At last, complete the high voltage cable in the ventilation roadway.

Withdrawing of equipment. Before withdrawing, make sure the rib, supports as well as scraper conveyer straight, and keep the roof and floor flat. At the same time, leave enough space for retracement. The sequence of dismantling is coal-cutter, former and back scraper conveyer and supports. Retreat the supports one by one in the panel from the bottom up and ensure the integrity of roof. Adjust the supports to straight in primary and second drawing hoist of JH-30. Then pull the supports upward to the roadway. The last two supports were directly pulled out of the panel in JH-30 drawing hoist out of the stop line. The retreated supports were hauled out of panel through drawing hoist and boom sheave.

Zone Controlling Technologies of Surrounding Rock along Inclination

Caving Shape of Overlying Strata and Ground Control along Inclination. When fully-mechanized caving in steeply dipping thick coal seam, broken top-coal and collapsed roof glides downward and fill the lower end, which lead different shape of overlying strata along inclination, uneven load of supports and lower normal support load [1-3]. Generally speaking, when mining steeply dipping seam, the strength of ground pressure is lower, and the load of supports is generally less than the rated load.

According to the different shape of overlying strata and rules of strata behaviors, the panel along inclination can be divided into densely packing zone on the bottom, non-uniformly packing zone in the middle and top zone affected by dynamic load(fig.1). In the densely packing zone on the bottom, the gob was densely filled by caving roof and gangue, which confines the rotation space of broken roof. Both the supports and gangue on the back bear the pressure of overlying strata together, which leads less weighting intensity and larger weighting distance. In the non-uniformly packing zone in the middle, caving roof has some rotation space and the average load of supports is larger. In the top zone affected by dynamic load, due to the component force of gravity along inclination, roof on the upside suspends, which results in lower load of supports at ordinary times but higher load while roof weighting. It shows evident characteristics of dynamic load. Besides, the suspending roof of upside zone will bring out the gliding even toppling of several supports in the panel. Therefore, the key point of ground pressure controlling is the upside roof. Safe mining in the panel can be guaranteed by increasing the setting load of supports, avoiding excessive drawing and handling the suspending zone in time. Secondly, limit the gliding and toppling of upside supports through the higher working resistance of gentle slope on the bottom.

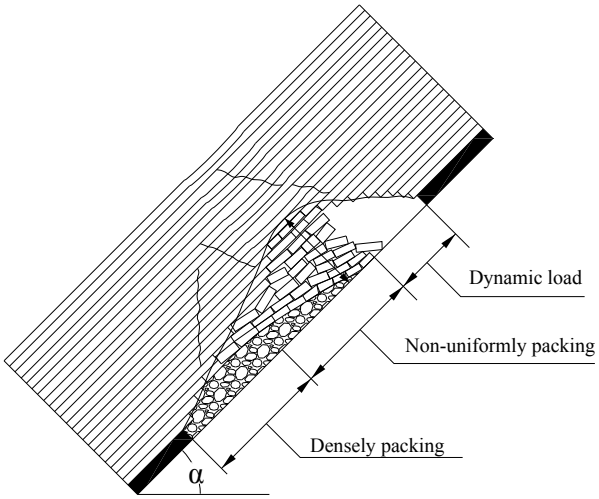

Fig.1 Overlying strata forms along the tilt direction

Stability Controlling of Floor. Because the floor in the panel will be soft after water absorption, the maintenance and management of supports must be strictly controlled. All kinds of pipelines in the panel must be strictly supervised to prohibit them from liquid leakage. And the coal dust in the panel must be handled by sweeping rather than washing in water.

Before all the equipment in the panel was installed, the floor and crosstie must be strengthened by bolt mesh(figure 2). The floor was strengthened by holoscrew and identity intensity anchor bolt with 18mm diameter and 1800mm length. The bolt was used cooperatively with tray of 150×150 ×10mm and steel belt guard of 350×280×3mm. The row and column spacing that the bolt was installed was 1300×1000mm. The floor must be widely laid with rhombic metal mesh, which is linked by iron wire every 200mm. To ensure the stability of track, the spacing of crosstie is 500mm and each crosstie must be fixed by one bolt.

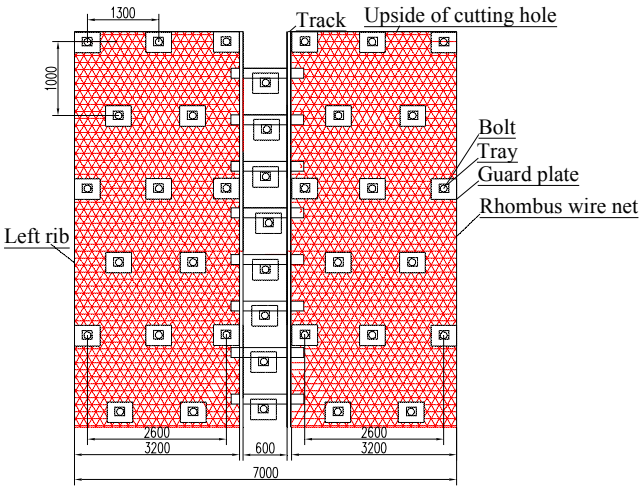

Fig.2 Reinforcement of floor in open-off cut

Stability Controlling Technologies of Equipment

The optimizing of roadway arrangement and support lectotype. As is shown in figure 3, the upside roadway was tunneled along the floor and the bottom roadway was tunneled along the roof of coal seam [4-8]. The circular section is a transition from the bottom roadway to the panel in order to prevent the toppling and gliding of supports. At the same time, the panel was false supine slanting arrangement. The bottom roadway was 3 to 5 meters ahead of the upside roadway and the angle of slanting backward is not more than 7 degree to decrease the dip angle of panel. The basic supports are ZFY4800/17/28 sublevel caving hydraulic support and the transitional supports are ZFG4800/18/32. Both of them are produced by Zhengzhou coal mining machinery group.

The design and lectotype was optimized through the combination of practical operating experience and special requirement to supports in the steeply dipping seam. The main technical improvements are as follows. Firstly, the height of side guard plate is higher than ordinary support, which is more suitable for adjusting support in steeply dipping seam. Double side guard plate prevent the coal leakage between supports. Secondly, the whole sealing base of support decreases the floor specific pressure and controls the activity range of pusher jack to limit the moving up and gliding of front scraper conveyer. Thirdly, two pillars chock-shield could prevent the uplifting of back pillar and falling down of supports, which will result in the insertion of supports to floor. Then, the support has liftable and lowerable joint front beam. It is beneficial for the layout of top wire, top brushing of coal-cutter and preserving roof in time. Finally, the pipelines of support are neat. There is enough space under the supports for men walking.

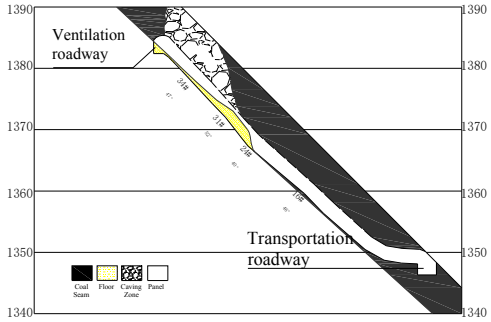

Fig.3 Profile map of measured roadway arrangement

Formation of Moving Supports. After cutting coal, move the supports from the top down according to different groups. During advancing the powered support, make the support with pressure and adjust the condition of support at any moment to keep the support perpendicular to rib and scraper conveyer. Move the second support on the bottom then the first one. After the last support on the tail moved forward, it's the turn of the third and the others to move to the place in which the coal-cutter is working. When the speed of moving support is slower than coal cutting, there needs stop the coal-cutter and wait for the supports. The first support on the bottom doesn't have a liability. After pushing the drive head, move the No.2 support first and then the No.1 and No.3 in turn.

Measurements of Anti-toppling. Before movement of supports, increase the setting load to at least 24MPa. Adjust the position of supports timely through the jacks on the side guard plate and bottom jacks. At the same time, keep a rational prop-setting angle to counteract the horizontal displacement of roof. Control the coal-cutting height at about 2.3m. Reduce the opposing time of top coal through fast moving supports and opening the flexible beam and side guard plates timely. The dip separation of upper beam between two adjacent supports could not be ±150mm more than the width of side guard plate. When adjusting the layout of panel, advance about 2 to 3 mining circulation after adjusting one time. Meanwhile, adjust the supports without delay to prevent extrusion of supports. Anti-gliding jacks are set up between supports to link all the supports. Anti-toppling jacks and chains can integrate the supports to one group to prevent the gliding and toppling of supports.

Skid Resistance of Coal-cutter. The coal-cutter cuts the coal from the top down. It doesn't cut coal when moving upward. The front scraper conveyer, following the coal-cuter, moves to the rib. And supply pressure to the scraper conveyer to push the coal-cutter to the rib in order to prevent the slip of coal-cutter when cutting coal. When stopping cutting coal, the two rollers are inserted into the rib and put down to the floor. Skid resistance pin are installed in the front scraper conveyer to prevent the coal-cutter from slipping.

Skid Resistance of Scraper Conveyer. When the scraper conveyer moves upward or downward, there needs to adjust the position of supports to make the bottom of support perpendicular to the scraper conveyer. At least two jacks must be arranged in the machine head to fix it. The jacks to prevent scraper conveyer from gliding are installed in the top of panel. When found the gliding of scraper conveyer, pull the back scraper conveyer to its primary rational position through jacks.

Optimizing of Drawing Technologies

Top coal caving is the key technologies in mining steeply dipping thick seam [9-12]. Due to the lager dip angle, top coal will roll and glide towards bottom along inclination after caving. Drawing coal has great difficulty in operation. It needs to ensure the stability of supports, increase the recycling rate and reduce the content of gangue. Meanwhile, protecting the upper roadway and preventing rib spalling as well as roof falling must be considered. Through the observation of migration law of top coal and the contrast of several drawing plan, coal drawing is not going at 5 supports in the top and bottom. And the top coal on the top roadway was strengthened to maintain the stability of top roadway (figure 4). The diameter of anchor cable is 17.8mm and its length is 7m. The row space is 3m. There are 3 anchor cable in one group. One cable was separately installed in the roof of ventilation roadway, vertical strata and horizontal strata. The cable is installed in the top of coal rib ramp. The spacing along advancing is 2.5m. The length of cable to the roof is 1.5m.

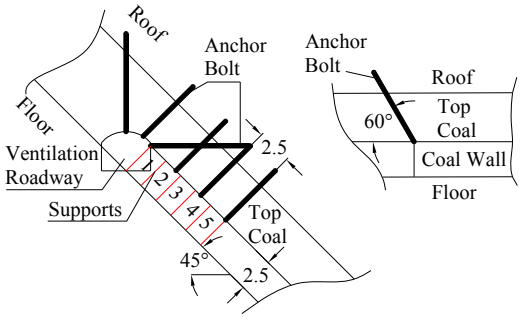

Fig.4 Schematic diagram of reinforcing top-coal in haulage roadway

The drawing sequence of panel must strictly be from top to bottom and interval caving coal between two cutting. The drawing space is 1.2m. Meanwhile, measurements must be taken as follows to prevent supports' instability due to excessive drawing. Improve the setting load of supports, take full advantage of face guard and move the support in time. Make use of front canopy and extensible canopy to reduce the tip-to-face distance. Accelerate the advancing speed and control the drawing time quantity.

Do not draw during the preliminary extraction. After the preliminary extraction, install the back scraper conveyer to draw top coal. Strictly control the drawing quantity during periodic weighting to prevent support from toppling. When there is gangue behind the support, local rib spalling and falling coal wall, it needs stop drawing immediately. During coal drawing, the roof condition of No.5 to No.10 supports above the drawing position should be observed by specially-assigned person. Supplement the pressure and hoist the support when there appears supports' gliding.

Summary

1) Fast transportation installation and withdrawal of equipment in the panel are achieved.

2) The stability of surrounding rock is ensured through zone controlling technologies along inclination combined with measurements of reinforcing floor. The stabilization of top roadway is also guaranteed during normal mining. It provides security for the stability of "roof-support-floor" system.

3) Through the optimization of roadway arrangement and support lectotype, moving support with pressure from top to bottom, taking full advantage of side guard as well as bottom jacks and increasing the setting load of support, the toppling and gliding of support are prevented. A series of technologies, such as continuously pushing scraper conveyer to prevent coal-cutter from gliding and anti-down jacks to stop scraper conveyer from gliding, is innovated to keep the equipment stable.

4) According to the movement regularity of top coal in steeply dipping seam, the targeted optimum extraction process is proposed. That is "not drawing coal behind 5 supports at the top and bottom respectively", "drawing from top to bottom" and "interval caving coal between two cutting". Safe effective technologies of drawing coal in the top end are achieved by reinforcing top coal with fan-shaped anchor bolt.

Acknowledgements

We are thankful for financial support from the Key Technology P&D Program, which is supported by The National Natural Science Foundation of China (grant No. 51374217 and No.51104162), the National Key Basic Research Program of China (grant No.2013CB227903) and the Specialized Research Fund for the Doctoral Program of Higher Education (grant No. 20120023120008).

References

[1] Wu Yongping. Study on dynamics controlling basis of system ”R-S-F” in steeply dipping seam mining[M]. Xi’an: Shaanxi Science and Technology Publishing House, 2006.

[2] Wu Yongping, Yun Dongfeng, Zhang Miaofeng. Study on the elementary problems of full-mechanized coal mining in greater pitching seam[J]. Journal of China Coal Society, 2000,25(5) : 465-468.

[3] Wu Yongping, Xie Panshi. Three-dimensional strata movement around coal face of steeply dipping seam group[J]. Journal of Coal Science & Engineering(China) , 2008, 14(3): 352-355.

[4] Wang Zhi-qiang, Zhao Jing-li, Li Ze-quan. Determination of height of “Three Zone” in the stope with stagger position and internal misaligned roadway layout [J]. Journal of Mining & Safety Engineering, 2013, 30(2): 231-236.

[5] WANG Zhi-qiang, ZHAO Jing-li, ZHANG Bao-you, et al．Stable characters of key stratum in stagger arrangement roadway layout top-coal caving mining [J]. Journal of China Coal Society, 2008，33(9):961-965.

[6] Huang Guochun, Wu Yongping, Li Ruming, et al. Technology of longwall top coal caving along the strike in hard roof， soft floor and coal steeply dipping seam[R]. Xi’an: Xi’an University of Science and Technology; Urumqi: Xinjiang Tar Coal Group Co.Ltd, 2009.

[7] Wu Yongping, Xie Panshi, Ren Shiguang. Analysis of asymmetric structure around coal face of steeply dipping seam mining[J]. Journal of China Coal Society, 2010, 35(2) : 182-184.

[8] Xie Junwen, Gao Xiaoming, Shangguan Kefeng. Long wall mechanized top caving techniques along strike in steep inclined thick coal seam[J] . Journal of China Coal Society, 2005, 30(5) : 545-549.

[9] Lin Zhongming, Chen Zhonghui, Xie Junwen, et al Stability analysis and control measures of powered supports in greater inclined full mechanized coal seam [J] . Journal of China Coal Society, 2004, 29(3) : 264-268.

[10] Zhang Zhiyan. Dynamic analysis on stability of hydraulic powered support in deep inclined fully mechanized wall and prevention slips measures[J]. Journal of China Coal Society, 2007, 32 (7): 705-709.

[11] WANG J C, YANG S L, LI Y, WEI L K and LIU H H. Caving mechanisms of loose top-coal in longwall top-coal caving mining method[J], International Journal of Rock Mechanics and Mining Sciences, 2014, 71(10): 160-170.

[12] Wang Jiachen, Zhang Jinwang. BBR study of top-coal drawing law in longwall top-coal caving mining[J]. Journal of China Coal Society, 2015, 40(3): 487-493.