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# Numerical Simulation of Coal Discharging Method in Working Face Combining Fully Mechanized Caving with Mining based on PFC Modeling

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**Abstract:** To improve the extraction efficiency of top coal at the working face through synergistic coordination of fully-mechanized mining and fully-mechanized caving, a research is conducted by employing PFC numerical simulation software applied to the engineering background of the 14022 working face combining fully mechanized caving with mining in Zhaogu mine. The study discusses the impact of round, segmentation, sequencing, and coal discharge outlet opening order. Based on the determination that single-round coal-loading is the optimal method, in comparison with the gangue content of single-round coal caving, the gangue content of the single-round sequential coal caving method is lower than that of the multi-round interval coal caving method. Considering both the top coal recovery rate and the gangue content as two criteria comprehensively, the single-round sequential coal caving method is the optimal coal caving method in Zhaogu mine.

**Keywords:** Fully-mechanized mining and caving, Top-coal recovery ratio, Numerical simulation, Coal caving method.

## I. Introduction

The application of top coal caving technology in coal seam mining from research and experimentation to widespread use is an achievement that can be attributed to China[1,2]. The coal recovery ratio has been one of the pivotal metrics in assessing the triumph of top coal caving technology[3]. Due to the high productivity and efficiency, as well as low tunnel excavation volume, fully-mechanized mining and fully-mechanized caving have become the principal mining methods for coal mining in China[4].

Among various influencing factors, the method of top coal extraction plays a critical role. In the event that the block size of top coal is large and does not meet the requirements for caving under comprehensive mechanized excavation[5,6], the flow of coal gangue induces the following issues, namely, large broken pieces of upper coal flow into the gob and cannot be extracted by caving[7]. When the large top coal blocks reach the point of extraction, their sizes in comparison with the extraction portal cause blockage[8]. The formation of an arch of top coal above the extraction portal, combined with the limited disturbance caused by the tail beam of hydraulic supports, is ineffective in disrupting the arched structure of the top coal, ultimately leading to termination of the caving process[9].

## II. Overview of Working Face and Coal Caving Method

The 14022 working face has a mining length of 1618 m and a recoverable reserve of 1.236 million tons. Based on the coal seam occurrence at the working face, the mining height ranges from 2.5 to 3 meters, with an average of 2.8 meters, which can be adjusted based on the actual coal seam occurrence and geological conditions. During the initial stage of extraction, the height of top coal hydraulic support is consistent with that of the bottom layer hydraulic support. To avoid the occurrence of steps, the cutting height of the coal seam in the extraction zone is set at 2.8 m, the caving height at 3.2 m, and the ratio of mining to caving is set at 1:1.14.

The method of top coal extraction not only has a significant impact on the coal recovery ratio and gangue content of the working face, but also affects the overall caving speed and the ability of the working face to achieve high productivity in a regular circulation. Therefore, different methods of top coal extraction can be formed based on the coal caving sequence and the caving volume of each cycle.

The basic information of various methods of top coal extraction is listed as follows,

(1). The sectional caving method involves dividing the working face into 2-3 segments with adjacent extraction portals in each segment opened simultaneously. The top coal is extracted from each segment by caving one-third to one-half of the total amount in a cyclic order until all the top coal in that segment is completely extracted. Then, the method moves onto the next segment or all segments operate concurrently.

(2). The multi-cycle caving method involves opening four extraction portals of different sizes at one end of the working face, with the area of each portal being 1, 1/2, 1/3, and 1/4 of the total. After the first portal finishes caving and is closed, the next portal is opened in a sequential order, while maintaining the size and sequence of the portal openings.

(3). The sequential caving method involves extracting the top coal in a cyclic order from extraction portals numbered as odd numbers, such as 1, 3, and 5, caving1/3 to 1/2 of the total amount in each cycle. Then, the caving process repeats for the numbered even portals, such as 2, 4, and 6, in the same order until all the top coal is completely extracted. This method reduces gangue content and improves coal recovery rate by maintaining a uniform top coal extraction rate.

(4). The equal caving method involves caving top coal from the odd numbered hydraulic supports first, such as 1, 3, and 5. When a certain amount of gangue is encountered, the extraction portal is closed, leaving the larger top coal blocks, followed by caving top coal from the even numbered hydraulic supports at a distance behind the odd numbered ones. This method results in less coal loss and gangue content, and is conducive to achieving high productivity and efficiency, making it an effective top coal extraction method.

## III. Model Design and Results Analysis

In order to maximize the extraction of top coal and improve coal recovery ratio, a simplified two-dimensional numerical model of top coal caving is developed based on the drilling column chart of working face and the actual engineering conditions in the vertical direction of the working face. Considering the limitations of the PFC simulation software, the model is appropriately simplified.

The numerical simulation model has a dimension of 45 m×22 m, with 30 extraction portals width of 1.2m along the vertical direction of the working face. To eliminate the boundary effect, three hydraulic supports at the edge are not used for top coal extraction, resulting in the use of 24 hydraulic supports for coal extraction. The height of the top coal is set at 3 m, and the numerical model is shown in Figure 1.

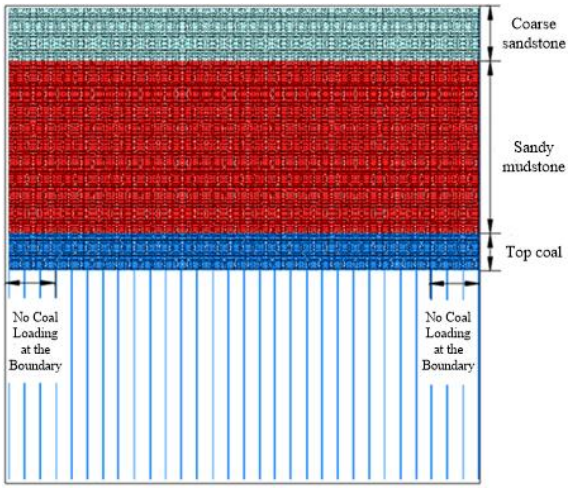
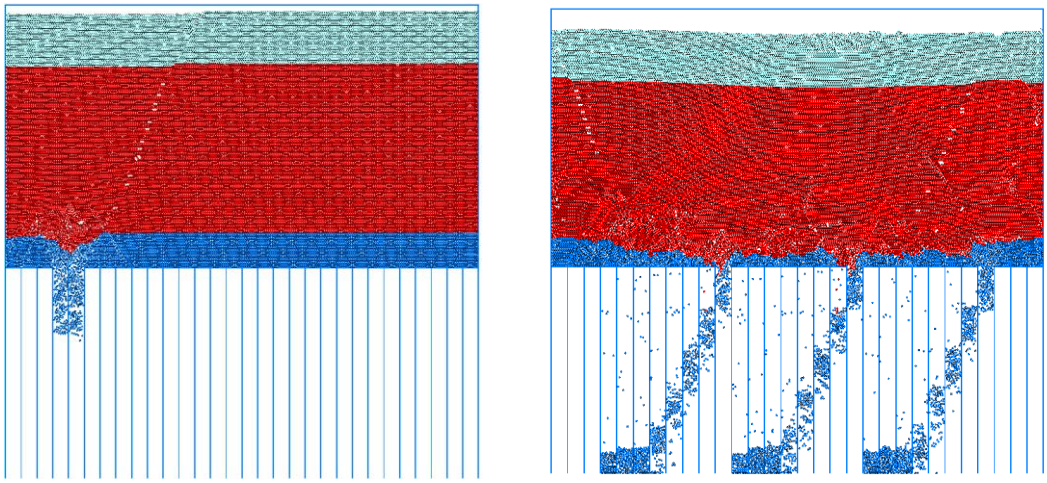



Figure 1 Model diagram for loading coal method

The numerical model is established to simulate the four schemes separately. The differences in coal discharge patterns between a single coal-discharging port and multiple ports under the same thickness of top coal are studied. The top coal discharge ratio and gangue content of the four schemes are compared to determine the optimal coal caving method.

(1). The working face is divided into three segments, each consisting of eight hydraulic supports. A coal-discharging port is opened within each segment until all the top coal is discharged, with adjacent ports opened in sequence. Meanwhile, three coal-discharging ports are simultaneously opened at the working face in a sequential 2round cycle, with each segment operated simultaneously. The simulated results of this coal caving process are illustrated in Figure 2.



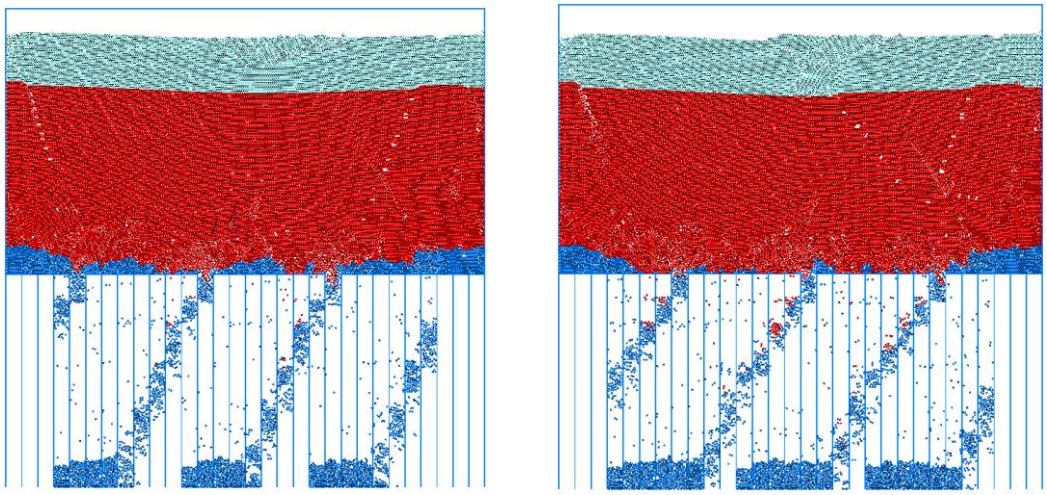


Figure 2 Simulation diagram for multi-round, segmented, and sequentially-discharged coal caving

During multi-round sequentially-discharged coal caving, a small amount of coal is released repeatedly to make the original boundary between top coal and rock sink evenly in sections, thus improving the recovery rate of top coal and reducing coal loss. However, in actual coal caving process, the coal-rock mixture around the ellipsoid funnel is also mixed into the loose top coal during multi-round coal caving, leading to top coal loss. Additionally, it is difficult to achieve a consistent amount of coal discharged from each support at each time, resulting in uneven sinking from each coal-discharging port.

As a result, an uneven final coal caving surface is formed, leading to more top coal loss. The more coal caving rounds there are, the more gangue is mixed in. Following the principle of closing the gangue door, the loss of top coal increases as well. From the above, it is obvious that after the first round of coal caving, the coal-gangue boundary surface presents an uneven, zigzag shape, with all coal-discharging ports discharging coal only.

In the second round of coal caving, some coal-discharging ports begin to have gangue mixed in, causing premature closure of coal-discharging port in actual production, resulting in some top coal unable to be discharged. By the third round of coal caving, it is apparent that a significant amount of top coal remains at the upper part of the closed coal-discharging ports, resulting in a severe loss of coal and low recovery rate of the top coal.

(2). From one end of the working face, adjacent coal-discharging ports are opened simultaneously. Whenever two coal-discharging ports are finished and closed, the adjacent coal-discharging ports are subsequently opened in sequence. The simulation results of this method are shown in Figure 3.

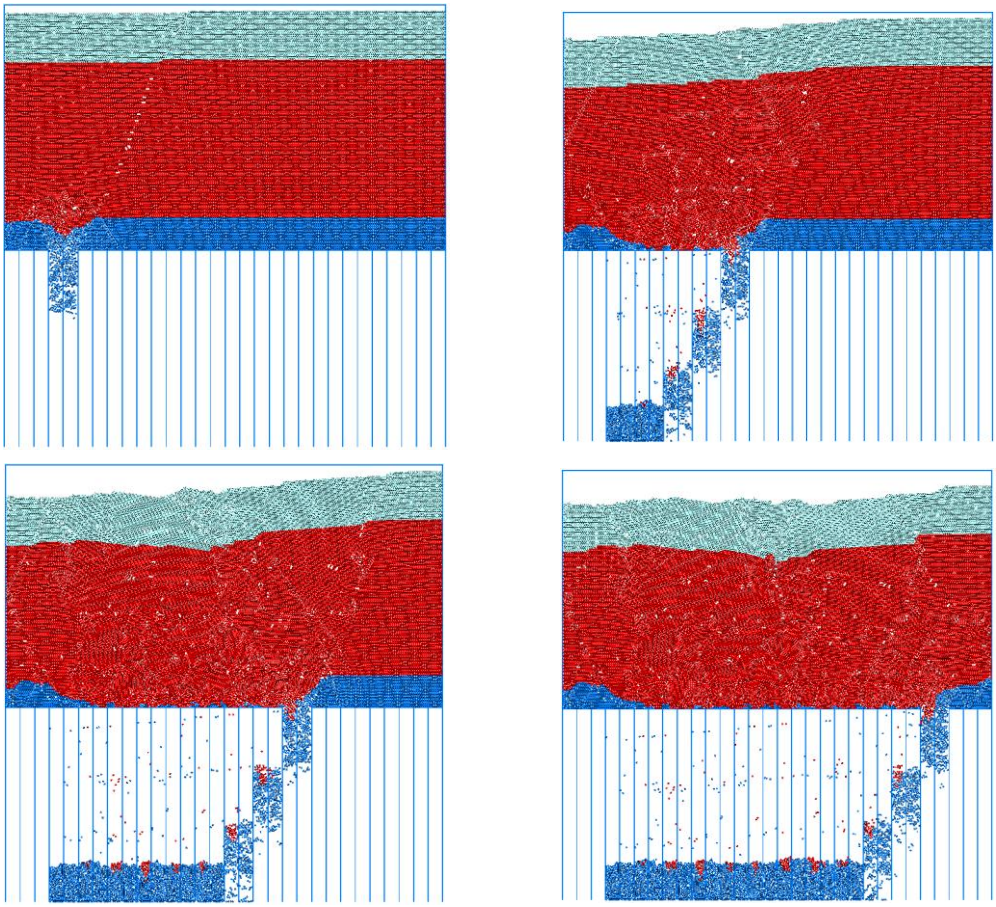


Figure 3 Simulation diagram for single-round, multi-port, sequentially-discharged coal caving

In this coal caving method, two hydraulic supports are opened to discharge coal at the same time. The top coal is gradually released during the coal caving process, making the operation simple, requiring relatively fewer personnel in the production process, and making it easy to control the extent of top coal release. Numerical simulation shows that the coal-rock boundary during the release is relatively regular in this method and the coal loss is minimal. However, the top coal from the previously discharged hydraulic support is easily mixed with the gangue through the next hydraulic support during the coal caving process, causing the top coal to mix with the gangue prematurely.

When the principle of closing the gangue door is adopted, it results in significant coal loss. On the other hand, if the gangue door is not closed, a large amount of gangue is likely to mix in during the later stages of coal caving, which affects the coal quality. In actual production, if this coal caving method is used, it is necessary to have a deep understanding of the law of top coal release on the working face, and balance the relationship between top coal recovery rate and gangue content.

(3). The coal is discharged in sequence from the odd-numbered coal-discharging ports, such as No. 1, No. 3, No. 5, and then from the even-numbered coal-discharging ports, such as No. 2, No. 4, No. 6, and so on. This process is repeated for two rounds until all the coal is discharged. The simulation result of this method is shown in Figure 4.

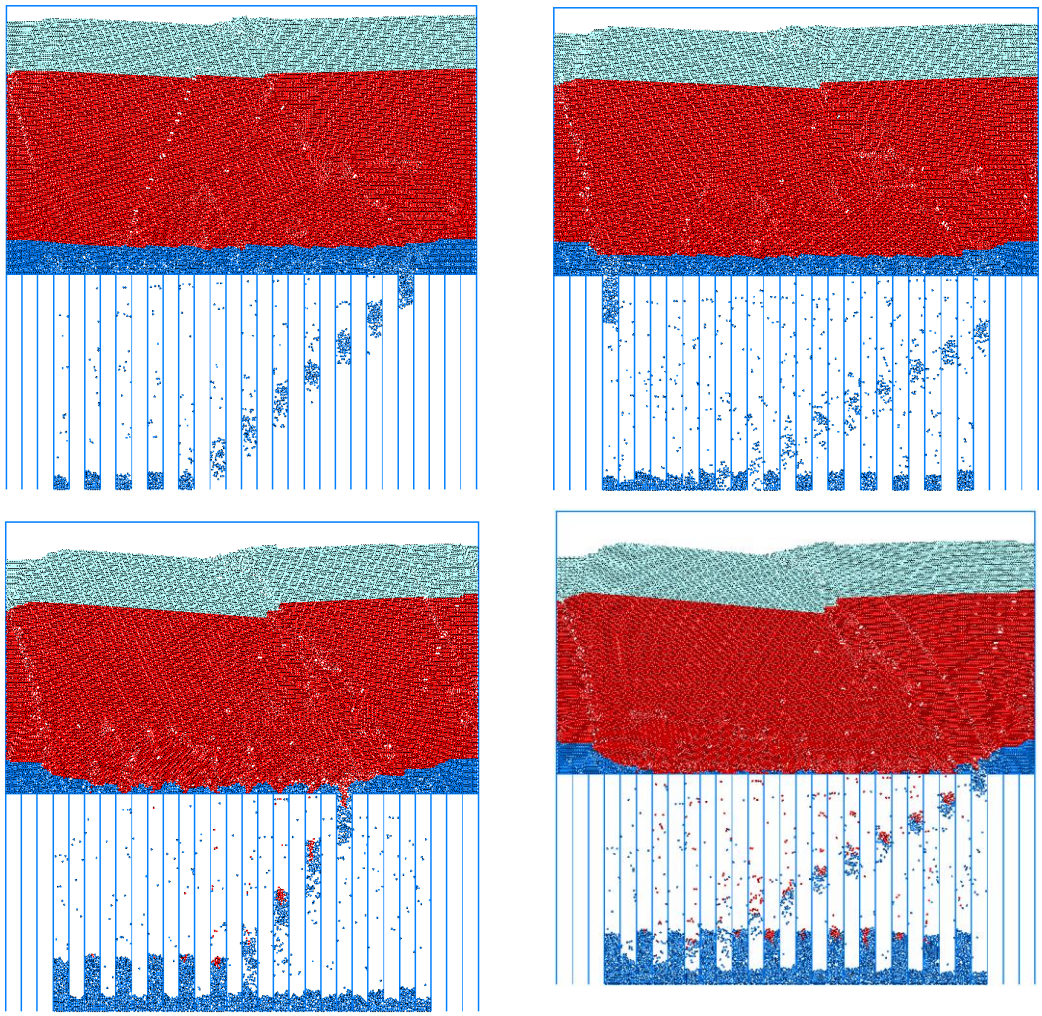


Figure 4 Simulation diagram for multi-round, interval, sequentially-discharged coal caving

In multi-round coal caving, both interval coal caving and sequentially-discharged coal caving methods result in the coal-rock mixture around the ellipsoid funnel being mixed into the loose top coal during the process of coal caving, leading to a higher gangue content in the top coal. At the same time, according to numerical simulation results, the coal-rock boundary formed by the top coal under the conditions of coal discharge from the coal-discharging port is irregular in this coal caving method, and the formation of an arch at the coal-discharging port during the coal caving process makes it difficult for the top coal to be discharged.

When the adjacent coal-discharging ports become arched, gangue is likely to surge out in advance, at which point the coal-discharging ports should be closed. After re-initiating coal discharge, some gangue appear as the top coal in the arched area. The coal-rock boundary formed by the top coal under the conditions of coal discharge from the coal-discharging port is irregular, and the remaining top coal layer above the hydraulic support is in continuous “M” shape distribution. The coal discharge time from each hydraulic support is the same. Most of the remaining top coal is discharged from the coal-discharging port due to the gravity.

The remaining top coal is compressed by gangue and slides into the adjacent odd-numbered hydraulic support, making it impossible for the top coal to be discharged, leading to top coal loss. As shown in the Figure 4, it is obvious that by the last round of coal caving, a significant amount of top coal still remains above the coal-discharging ports, resulting in severe coal loss and a relatively low top coal recovery rate.

(4). The odd-numbered hydraulic supports, such as No. 1, No. 3, No. 5, are firstly employed to discharge coal. The coal on the even-numbered hydraulic supports, such as No. 2, No. 4, No. 6, is discharged three hydraulic supports later. This method is completed in one cycle. The simulation results are shown in Figure 5.

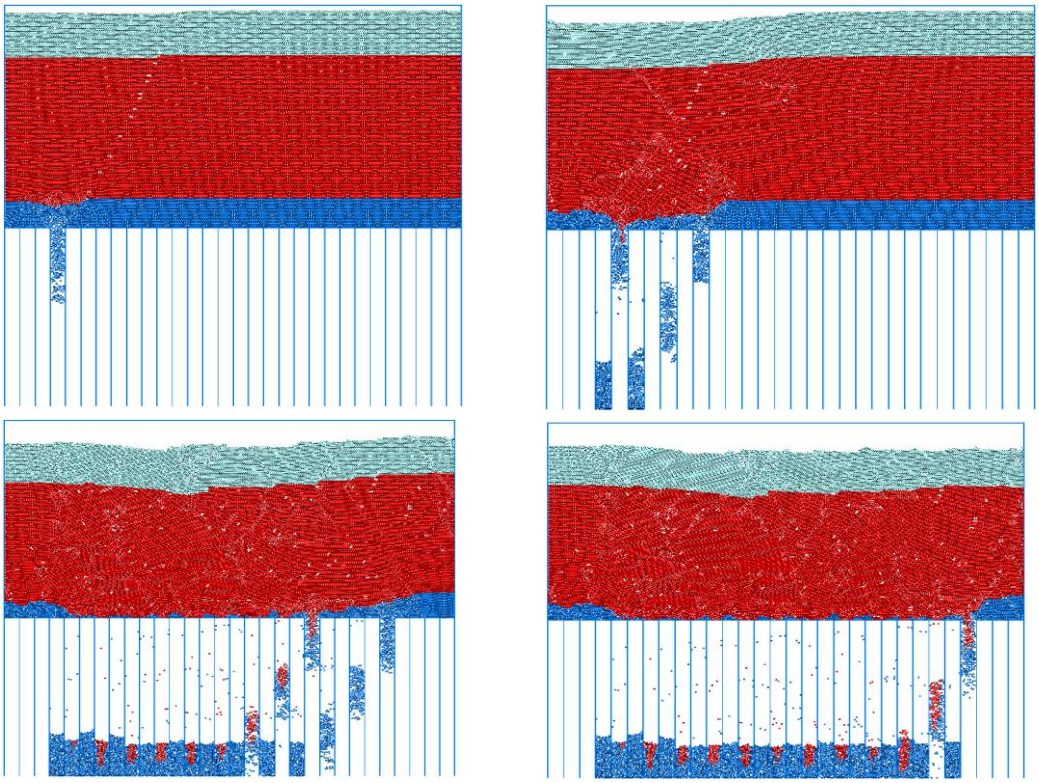


Figure 5 Simulation diagram for single-round, multi-port, interval coal caving

In this coal caving method, according to numerical simulation results, it is obvious that when the top coal is discharged, the time at which the gangue is discharged from the coal-discharging port is relatively early. In actual production, this can easily cause the coal-discharging ports to be closed prematurely, resulting in most of the top coal not being discharged. In numerical simulation, the coal-rock boundary formed by the top coal under the conditions of coal discharge from the coal-discharging port is irregular, and the top coal cannot be fully recovered before the gangue reaches the coal-discharging port, leading to an irregular coal-rock boundary. The gangue reaches the coal-discharging port, causing early termination of coal caving at that port, resulting in coal loss.

## IV. Conclusion

Comparing the top coal recovery rate of different coal caving methods, the top coal recovery rate of single-round coal caving is generally higher than that of multi-round coal caving. Based on the determination that single-round coal-loading is the optimal method, in comparison with the gangue content of single-round coal caving, the gangue content of the single-round sequential coal caving method is lower than that of the multi-round interval coal caving method. Considering both the top coal recovery rate and the gangue content as two criteria comprehensively, the single-round sequential coal caving method is the optimal coal caving method in Zhaogu mine.

## V. Acknowledgements

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## References

[1] Shang Haitao, Wu Jian. On the necessity of development fully-mechanized mining with sublevel caving in China [J]. China Coal, 1997 (04): 2-7.
[2] Meng Xianrui, Wang Hongpeng, Liu Chaohui, Zhang Ying. Selection principle and development status of thick seam mining methods in China [J]. Coal Science and Technology, 2009, 37(01): 39-44.
[3] Wu Jian. Theory and practice of sub-level caving method in China [J]. Journal of China Coal Society, 1991(03):1-11.
[4] Meng Xianrui, Wu Haotian, Wang Guobin. Development of thick coal seam mining technology and selection of mining methods in China [J]. Petrochemical Industry Technology, 2014, 46(10): 43-47
[5] Chen Zhonghui, Xie Heping, Lin Zhongming. Study on falling ability of top coal during top coal caving by damage mechanics [J]. Chinese Journal of Rock Mechanics and Engineering, 2002(08): 1136-1140.
[6] Song Xvanmin, Qian Minggao, Jin Zhongming, Study on the fragmental distribution's regularity of top-coal fractured experiment for top-coal caving mining [J], Journal of China Coal Society, 1999(03): 39-43.
[7] Zhang Yong, Si Yanlong, Shi Liang. Numerical simulation of the effect of particle size on coal caving ratio [J]. Journal of Mining & Safety Engineering, 2011, 28(02): 247-251.
[8] Huang Bingxaing, Liu Changyou, Niu Hongwei, Wang Jun. Research on coal-gangue flow field character resulted from great cutting height fully mechanized top coal caving[J], Journal of Mining & Safety Engineering, 2008,25(04):415-419.
[9] Shi Pingwu, Zhang Youzhen. Structural analysis of arch of spanning strata of top coal caving in steep seam [J]. Chinese Journal of Rock Mechanics and Engineering, 2006(01): 79-82.