Optimization of Structural Parameters of Stope without Sill Pillar in Metal Mine by Computer Numerical Simulation

You Lin¹,*

¹Faculty of Metallurgy and Mining, Kunming Metallurgy College, Kunming, Yunnan, China, 650033

*Corresponding author e-mail: linyou507@kmyz.edu.cn

Abstract. The determination and optimization of stope structure parameters is of great value in reducing the ore loss and dilution in the mining process, improving the production capacity of the stope, increasing the workload of mining and mining, reducing the investment cost of the mine and improving the mining efficiency. Based on this, this paper first analyses the parameter changes of stope structure parameters without sill pillars in metal mines, and then studies the optimization of structural parameters of stopes without sill pillars in metal mines based on orthogonal test method.

Keywords: Structural Parameters, Sill Pillar, Metal Mine, Computer Numerical Simulation

1. Introduction
As a mining method with high mechanization, high safety and low operation cost, sublevel caving without sill pillar uses drift to cut ore body, and then uses medium deep hole drilling to carry out ore drawing operation in drift. With the gradual maturity of pillarless sublevel caving method, it has been popularized and popularized in various ore mining processes [1]. As the core operation content of mining method, the determination and optimization of stope structure parameters is of great value in reducing the ore loss and dilution in the mining process, improving the production capacity of the stope, increasing the workload of mining and mining, reducing the investment cost of the mine and improving the mining efficiency.

In addition, with the continuous updating and iteration of mining technology and the updating of mining equipment, the stope structural parameters based on pillarless sublevel caving method are also gradually upgraded and optimized, mainly reflected in the continuous increase of stope structural parameters with the development of mining equipment, and the development of stope structure in the direction of large-scale and accurate mining technology [2]. These advanced mining technology, industry and equipment need more advanced mining structure parameters to provide support. Therefore, it is of great practical value to study the computer numerical simulation optimization of structural parameters of pillarless stope in metal mines.

2. Parameter Variation of Stope Structure Parameters without Sill Pillar in Metal Mine
2.1. Evolution process of stope structural parameters
Since its application, the Stope Parameters of 10 m × 10 m or 8 m × 8 m have been mostly adopted in the early stage. Since then, in the application practice of non-pillar stope in metal mine, the main purpose is to increase the drawing height by adding high-end wall, so as to reduce the mining preparation ratio and improve the mining efficiency [3]. However, in the actual operation process, due to the restrictions of drilling and charging conditions in the mining area, the amount of one-time ore collapse in the direction of ore drawing height, different rock drilling and blasting structure is much more than that of the ordinary method, which makes the capacity of large-scale ore drawing equipment play and the mining intensity is improved.

Since then, with the progress of mining technology and the improvement of equipment, some large-scale metal mines have gradually applied large parameter stope structure, and the sublevel height and drift spacing have been gradually increased. These metal mines with large parameters stope structure improve the mining efficiency, reduce the mining cut ratio and reduce the mining cost.

2.2. Selection of stope structure parameters without sill pillar in metal mine
The design and application of stope structure without sill pillar and the determination of structural parameters are mainly based on engineering experience and analogy method. For most metal mines, the small structural parameters adopted have the disadvantages of less ore collapse at one time and large mining cutting ratio. In addition, the difference of block composition will have a significant impact on Stope Parameters, and the eccentricity of drawing body will have a certain effect on the change of three-dimensional development parameters.

The parameter selection of stope structure without sill pillar in metal mine can be determined by sampling test based on its actual blasting fragmentation [4]. In the design stage of metal mine, the parameter selection of stope structure is mainly determined based on analogy method. The structure of ore body can be analyzed through the engineering geological survey of metal storm, so as to predict the block size distribution and determine the height of section. In addition, scientific and reasonable 3D parameters of metal mines should be simulated and analyzed during production, so as to adjust the spacing and jumping step distance.

2.3. Structural parameter index of stope without sill pillar in metal mine
At present, the main way of metal drawing is the cut-off grade ore drawing mode of pillarless sublevel caving mining method. In the process of metal ore drawing, with the ore being discharged, the surrounding rocks are gradually released. During ore drawing in dilution stage, the amount of ore in the bucket will gradually decrease, the rock entering from the surrounding area will gradually increase, and the ore grade in each bucket will gradually decrease. The main indicators of related pillarless metal mines are shown in Table 1 below.

| Metal mines | Dilution | Rate of recovery |
|------------|----------|-----------------|
| Mines 1    | 22.24    | 77.11           |
| Mines 2    | 19.50    | 89.41           |
| Mines 3    | 39.24    | 84.19           |
| Mines 4    | 14.24    | 84.34           |
| Mines 5    | 26.15    | 19.32           |
| Mines 6    | 31.32    | 96.31           |
| Mines 7    | 15.68    | 73.25           |

3. Optimization of Stope Structure Parameters without Sill Pillar in Metal Mine Based on Orthogonal Test Method
3.1. Orthogonal combination experiment design

Based on the principle of reducing test time and workload, the cross combination test is designed, and the test points are selected within the test range. Based on the principle of equilibrium and orthogonal test, in the computer numerical simulation, the factors such as section height, drift distance and caving step distance are selected for the test, and the reasonable test combination is set as shown in Table 2. According to the orthogonal combination design of each factor level, multiple groups of model tests are carried out.

| Horizontal Parameter | Group 1 | Group 2 | Group 3 |
|-----------------------|---------|---------|---------|
| Section height        | 11      | 15      | 19      |
| Route spacing         | 11      | 14      | 17      |
| Caving interval       | 3       | 4       | 5       |

3.2. Numerical simulation test

Based on the computer software to simulate the caving law of metal ore block, the influence of sublevel height, drift distance and caving step distance is accurately simulated and analyzed to find out the ore movement law in the non-pillar sublevel caving method. Using computer software to study the caving law of metal ore block, the different structural parameter models shown in Table 2 are calculated.

In addition, based on the computer software simulation model, based on the actual size of the metal stope, ore body occurrence conditions and equipment production capacity, and based on the form of computer command, the specific parameter values of section height, drift spacing, drift size and stope width in the structural parameter model of metal mine are established.

3.3. The persistence of monetary policy shocks

Firstly, on the particle size level, in order to better reflect the uneven size of ore and waste rock in metal mines, it is set that the particle samples should be composed of particle units with different radii, and reflect the variation of particle radius distribution. It is found that the speed of computer numerical simulation will be affected by the change of particle radius and the calculation speed will be significantly reduced with the increase of the number of particles in the model.

Secondly, at the particle specific gravity level, the particle specific gravity of ore and waste rock in metal mine and other basic calculation parameters of numerical simulation are shown in Table 3.

| Particle | Friction | Normal contact stiffness of particles | Particle stiffness ratio | Normal bond strength of particles | Tangential bond strength of particles |
|----------|----------|--------------------------------------|-------------------------|----------------------------------|--------------------------------------|
| 0.2      | 0.4      | 1e8                                  | 1                       | 0                                | 0                                    |

3.4. Analysis of optimization results of computer simulation

The summary data of different ore drawing results are grouped, so as to carry out computer simulation and optimization of ore drawing simulation test indexes of different drift spacing with specific section height. The results are shown in Figure 1 below. By comparing the comprehensive recovery rate and dilution rate results of different layered ore drawing with the field production results shown in Fig. 1, it can be seen that the recovery index of different simulation schemes is generally high, while the dilution rate is low. This indicates that there are different degrees of intercalation in the ore body of the metal mine, which leads to the increase of the dilution rate index and the decrease of the recovery rate index. However, the influence of waste rock is ignored in the simulation process, which makes the change of recovery rate and dilution rate.
In addition, the ore loss caused by the end is ignored in the simulation process, so the recovery index is higher than the actual index. Through the simulation results, it can be seen that the backwardness difference can be used as one of the criteria to evaluate the structural parameters of stope, and the optimal scheme can be determined based on the different schemes shown in Fig. 1.

![Graph showing rate of recovery and dilution](image)

**Figure 1.** Optimization results of computer simulation

4. Conclusion
In summary, with the continuous updating and iteration of mining technology and the updating of mining equipment, the stope structural parameters are gradually upgraded and optimized, which is mainly reflected in the continuous increase of stope structural parameters with the development of mining equipment, and the stope structure of mining technology is becoming larger and more accurate. In this paper, through the analysis of the parameter change of the structure parameters of the stope without sill pillar in the metal mine, and design the numerical simulation of different schemes of the stope structure of the metal mine based on the orthogonal test method, so as to analyze and select the best parameter optimization results.

References
[1] L. Cai, J. J. Ma, Study on computer stochastic simulation of ore drawing by caving method. Mining research and development, 2014, 24 (6): 57-59.
[2] Y. Feng, W. J. Wang, Z. Y. Han, Study on stope size optimization of pillarless sublevel caving in beimiaohe iron mine. China mining engineering. 2015, 34(2):18—21.
[3] G. L. Zhang, J. Song, X. G. Liu, Experimental study on structural parameters of sublevel caving along vein in Zhangjiawa iron mine. China mining, 2015, 14 (9): 45-48.
[4] X. B. Liu, S. Xu, H. R. Sun, Pillarless sublevel caving with large parameters and multi sublevel parallel non dilution drawing. China mining, 2016, 15 (7): 46.49.
[5] Y. Feng, W. J. Wang, Z. Y. Han, Study on stope size optimization of pillarless sublevel caving in beimiaohe iron mine. China mining engineering. 2015, 34(2):18—21.
[6] X. Dong, H. W. Deng, Stope parameter optimization of sublevel caving without sill pillar in Xiadian gold mine. Mining technology, 2019.9 (3): 4-6.