Optimization of ventilation system in deep well gold mine based on Ventsim

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Abstract: To address issues like excessive energy consumption, insufficient deep air intake, and improper airflow control, optimizations were made to both the shallow and deep ventilation systems. By conducting comprehensive wind measurements across the entire mine, the distribution of underground wind speed and airflow was thoroughly understood, allowing for an analysis of the mine's ventilation capacity and wind resistance. A theoretical model of underground ventilation and wind resistance was developed using Ventsim software. Additionally, a three-dimensional numerical model of Linglong Gold Mine's ventilation system was created with three-dimensional ventilation numerical simulation software. This model facilitated dynamic airflow simulation within the ventilation system, enabling the proposal of optimization and adjustment plans. The effects of air regulation were simulated and analyzed to optimize the ventilation network. Results indicate that, following the optimal adjustment scheme for deep airflow distribution, airflow disorder can be resolved and air supply in deep mining areas can be increased, effectively addressing the issue of insufficient air supply there. Post-optimization, the ventilation system's stability is improved, and air volume distribution becomes more reasonable, providing valuable guidance for Linglong Gold Mine's ventilation management.

1. Introduction

Mine ventilation system, as a complex but crucial part of mine production, its main function is to ensure the air circulation in the mine to introduce fresh air and discharge dirty air, so as to maintain the safety and comfort of the mine operating environment[1]. Mine ventilation system is the core link of mine safety production[2]. Linglong Gold Mine's ventilation system encounters problems like high energy consumption, insufficient deep air intake, short airflow, and ineffective airflow control. With increasing mining depth, the underground ventilation system experiences more stress. Therefore, it is necessary to reduce the complexity of the ventilation system[3]. The establishment of a perfect mine ventilation system has far-reaching significance for realizing the sustainable development of the mine[4]. Therefore, innovative research on optimizing ventilation systems through simulation and data mining is essential.

In recent years, some scholars[5, 6] have completed a number of research works on mine ventilation optimization mainly from the aspects of air volume regulation and energy consumption control.

Targeting the issues in Linglong Gold Mine's ventilation system, optimization research is conducted. Initially, wind measurement across the entire mine is performed according to the existing ventilation system's plan to determine air and deep mining area cooling needs. Then, a three-dimensional numerical model of the mine's ventilation system is established using Ventsim 3D software for dynamic airflow simulation. Finally, an optimization plan for air volume distribution in the deep mining area is developed based on field investigation and simulation analysis results.

2. Engineering background and problem analysis

2.1. Overview of mine ventilation system

Linglong Gold Mine employs mechanical extraction ventilation, utilizing a diagonal system with mixed well and auxiliary ramp air intake, and blind well and air well relay air return. Fresh air flows into the mine via the mixed well and auxiliary ramp, moves to the stope cleaning face through the middle roadway, and dirty air is expelled to the surface via the return roadway, blind air shaft, and air shaft. Fans are installed in the fan chambers at the -180m, -260m, and -420m midpieces. The mine's ventilation system is complex, and on-site investigation identified 5 main ventilation routes:

(1) Main ventilation route I (maximum ventilation resistance): mixing well→-660m midpiece→-660m~-980m ramp→-980m~-870m ramp→-870m~-820m ramp→-820m~-660m ramp→-660m~-600m ramp→-600m~-520m ramp→-520m~-510m ramp→return air shaft.(2) Main ventilation route II: mixing well→-180m midpiece→air shaft.(3) Main ventilation route III: mixing

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well→-260m midpiece→air shaft.(4) Main ventilation route IV: mixing well→-420m midpiece→air shaft.(5) Main ventilation route V: mixing well→-660m midpiece→-660m~-600m ramp→-600m midpiece→-600m~-540m shaft→-540m~-420m shaft→-420m midpiece→air shaft.

2.2. Problem analysis of mine ventilation system

During resistance measurement and analysis, the main issues in Linglong Gold Mine's ventilation system are identified as:

(1) High mine ventilation resistance and negative pressure, numerous mining areas with tight wind supply, many underground air volume adjustment facilities, and low ventilation management level.(2) Long mine inlet and return air routes, low ratio of wind section resistance to total mine resistance, and low effective air volume rate.(3) High stope temperature at -660 midpiece in summer, long air supply route, and insufficient ventilation and cooling air volume and quality to meet deep wind point cooling needs.

3. Analysis of air demand and modeling of ventilation system in deep mining area

3.1. Calculation of required air volume

The mine's total air volume is determined using the sub-calculation method, which involves calculating the ventilation volume based on the production characteristics of different workplaces and then multiplying it by the mine's air leakage coefficient to obtain the total air volume. The formula for calculating the entire mine's total air volume is as follows:

$$Q_t = K\left(\sum Q_s + \sum Q_s^{'} + \sum Q_d + \sum Q_r + \sum Q_t\right) \quad (1)$$

Formula: Q_s —Air required in stope, m³/s; $Q_s^{'}$ —Air required for backup stope, m³/s; Q_d —The amount of air required to drive the roadway, m³/s; Q_r —The air demand of an independent return air chamber, m³/s; Q_t —Air quantity required for ventilation and cooling, m³/s; K —Coefficient of mine air leakage, Take 1.3;

The -660m midpiece stope should account for ground temperature and air compression effects, increasing air supply for better cooling. With an average wet-bulb temperature of 29.8°C and 92.5% relative humidity, the cooling wind speed is 1m/s. There are 6 working faces below the -660m midpiece stope. Due to proximity and series relationships, they're treated as one mining area for air volume calculation, resulting in a cooling air volume of 24.56m³/s. The total air demand for Linglong Gold Mine is calculated at 163.23m³/s.

3.2. Three-dimensional visual modeling of ventilation system

The three-dimensional visualization model of ventilation system of Linglong Gold Mine was established by using Ventsim 3D simulation software and field measurement data. The modeling steps are as follows:

(1) Draw the CAD pattern of the roadway center line using the excavation engineering plan with elevation.(2) Import the roadway center line's dwg. file into Ventsim software and convert it into a solid roadway.(3) Detect and correct the connectivity of the preliminary mine model's roadways.(4) Shaft setting.(5) Air duct setting.(6) Input roadway ventilation parameters.(7) Fan settings.(8) Improve the mine model.

The model has 5512 branches and 4875 nodes, and is equipped with 4 main fans, 9 auxiliary fans and 6 damper. Fig 1 shows the three-dimensional visualization model of the ventilation system.

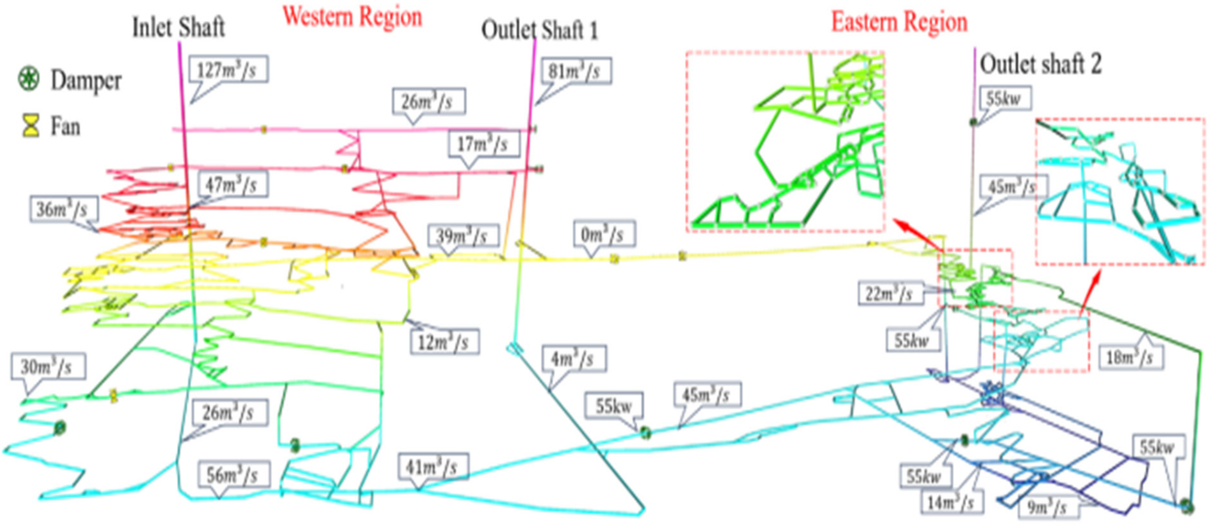

Figure 1 Ventsim 3D simulation model

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4. Optimization scheme and Ventsim solution based on sensitivity matrix

4.1. Calculation and result analysis of air volume sensitivity

The ventilation system of Linglong Gold Mine is simplified into a ventilation network through zoning, as shown in the figure 2 below, Wind resistance column vector R=(1.3734, 1.4715, 1.1772, 0.9810, 0.7848, 2.9430, 0.5886, 3.9240, 4.1202, 5.8860, 2.2467)^T, Call the self-made ventilation network solution program based on MATLAB, Solve the air volume column vector Q=(8.6551,8.1928,4.5612,5.3998,7.5355,2.4254,11.6295 ,5.2184,4.0939,2.7930,16.8478)^T.

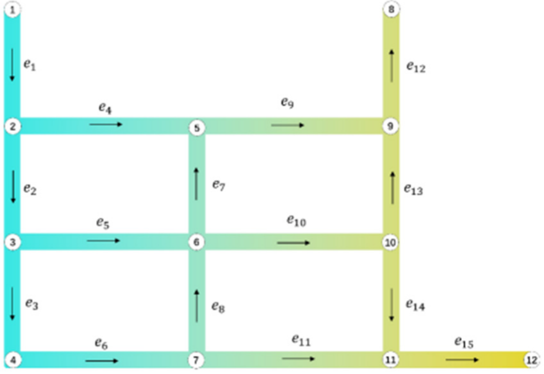

Figure 2 Ventilation network diagram

The calculated sensitivity matrix S_R^Q is shown below:

$$S_R^Q=\begin{pmatrix}
129.81 & 34.55 & 5.96 & 5.99 & 2.25 & 5.96 & 0.05 & -0.25 & 2.9 & 5.15 & 6.93 & 17.37 & 0.85 & -0.01 & 11.41 \\
79.97 & 52.73 & 6.35 & -5.07 & 4.07 & 6.35 & -0.2 & -0.09 & 1.27 & 3.12 & 5.11 & 9.46 & 0.96 & 0.01 & 7.42 \\
29.96 & 13.68 & 14.45 & -0.22 & -1.82 & 14.45 & 0 & 0.35 & -0.11 & -0.56 & 4.34 & 2.07 & 0.81 & 0 & 3.23 \\
49.85 & -18.16 & -0.38 & 11.06 & -1.81 & -0.38 & 0.26 & -0.15 & 1.65 & 2.05 & 1.83 & 7.92 & -0.1 & 0 & 4 \\
50.01 & 39.05 & -8.1 & -4.84 & 5.89 & -8.1 & -0.2 & -0.44 & 1.38 & 3.68 & 0.77 & 7.38 & 0.15 & 0.01 & 4.19 \\
29.96 & 13.68 & 14.45 & -0.22 & -1.82 & 14.45 & 0 & 0.35 & -0.11 & -0.56 & 4.34 & 2.07 & 0.81 & 0 & 3.23 \\
14.46 & -24.8 & -0.12 & 8.66 & -2.57 & -0.12 & 0.4 & -0.26 & -3.14 & 3.51 & 3.28 & -6.07 & 2.98 & 0 & 3.8 \\
-26.43 & -4.32 & 7.4 & -2.01 & -2.11 & 7.4 & -0.1 & 0.89 & 0.87 & 2.78 & -7.06 & 0.08 & -1.32 & 0 & -3.48 \\
35.39 & 6.63 & -0.27 & -37.33 & 0.75 & -0.27 & -0.14 & 0.09 & 4.77 & -1.48 & -1.46 & 13.98 & -3.9 & 0 & 0.18 \\
38.03 & 9.92 & -0.82 & 1.8 & 1.21 & -0.82 & 0.09 & 0.19 & -0.89 & 9.97 & -3.01 & 1.4 & 1.81 & 0.01 & 4.51 \\
56.4 & 18 & 7.05 & 1.78 & 0.29 & 7.05 & 0.1 & -0.54 & -0.98 & -3.34 & 11.4 & 1.99 & 2.14 & 0 & 6.71 \\
41.72 & 9.84 & 1 & 2.29 & 0.8 & 1 & -0.06 & 0 & 2.79 & 0.43 & 0.59 & 53.86 & 12.37 & -0.01 & -11.54 \\
6.33 & 3.21 & 1.27 & -0.1 & 0.05 & 1.27 & 0.09 & -0.1 & -1.99 & 1.91 & 2.05 & 39.88 & 15.47 & -0.01 & -11.73 \\
31.7 & 6.71 & -2.08 & 1.9 & 1.16 & -2.08 & 0.01 & 0.29 & 1.09 & 8.06 & -5.06 & -38.48 & -13.66 & 0.02 & 16.24 \\
88.09 & 24.71 & 4.96 & 3.69 & 1.45 & 4.96 & 0.11 & -0.25 & 0.12 & 4.72 & 6.34 & -36.49 & -11.52 & 0.01 & 22.95
\end{pmatrix}$$

4.2. Formulation of optimization scheme

Based on ventilation zoning and sensitivity matrix analysis, Linglong Gold Mine's ventilation system primarily suffers from inadequate air intake in the east area, necessitating increased air volume in Branch e_{15}. The sensitivity matrix analysis reveals that air volume can be increased in branches e_1, e_2, e_3, e_6, e_{11}, and e_{14}, with Branch e_1 being the most effective for regulation due to its role as the air inlet shaft. Conversely, air volume can be reduced in branches e_4, e_5, e_7, e_8, e_9, e_{10}, e_{12}, and e_{13}, with Branch e_{12} being the most effectively regulated branch since it's the return air well. Additionally, the absence of wind near branches e_9 and e_{10} allows for significant air volume reduction in these branches.

According to the sensitivity matrix calculation results, make the following adjustments to the ventilation system in Table 1.

Table 1 Ventilation system optimization scheme

Optimized location	Present condition	Optimization scheme
-660m level	two 55kW fans	Change to 90kW fans
East End return air	55kW fan	Add a 55kW fan
West -180m level	55kW fan;Air volume 30~50m³/s	Remove the fan and add a regulating window
West -260m level	55kW fan;Air volume 30~50m³/s	Remove the fan and add a regulating window
West -280m level		Add damper
West -310m level		Add damper
West -320m level		Add damper
West -330m level		Add damper
West -340m level		Add damper
West -350m level		Add damper
West -360m level		Add damper
West -370m level		Add damper
West -260m level	Air leakage in goaf	Add a 30kW fan Add damper Containment wall

4.3. Optimization plan Ventsim solution analysis

After the optimization scheme of the ventilation system is determined, Ventsim software is used to simulate and calculate the optimized ventilation system, and the calculation results are shown in Fig. 3.

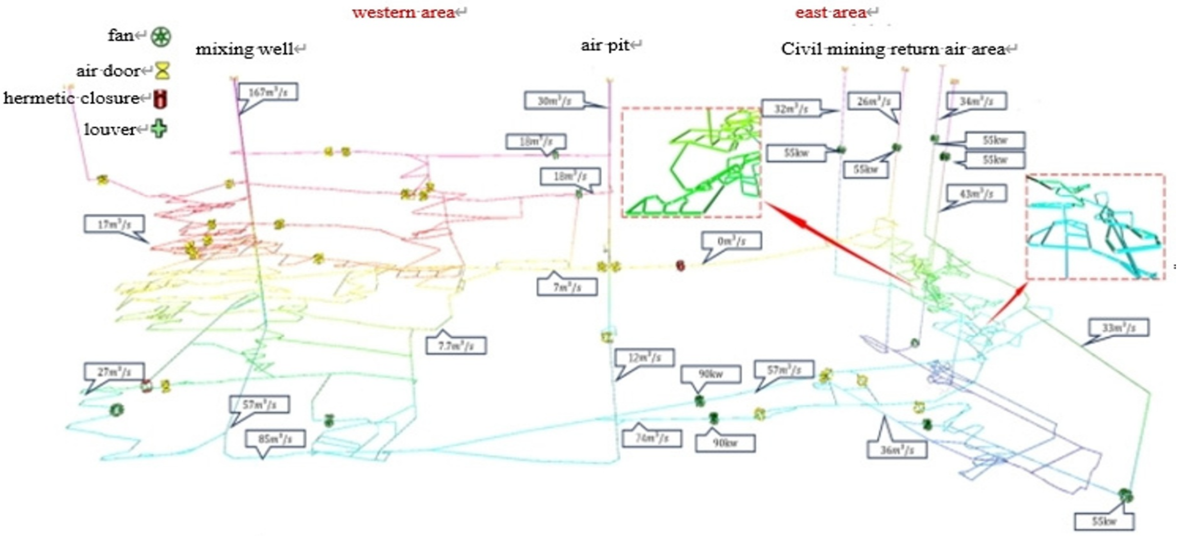

Fig. 3 Ventsim simulation of ventilation system optimization scheme based on zoning control

Simulation calculations show the mine's total inlet and return air volume is 167.2m³/s, aligning with the designed volume and meeting mine demands. Wind speed checksa for the main wind shaft, roadways, and slopes comply with safety regulations. The eastern mining area's effective air volume is 130m³/s, with a 34.65% increase in total intake air volume post-optimization. The air volume qualification rate rose to 94.73%, a 31.4% improvement. In the eastern district below -660m, the mining area's total air volume increased by 43.62% post-optimization, while the air volume of the three main laneways rose by 71.43%, 66.67%, and 66.67% respectively.

5. Conclusion

Based on the current state of Linglong Gold Mine's underground ventilation system, the mine's and deep stope's air demand were calculated, and a three-dimensional Ventsim ventilation numerical model was established to analyze and optimize the ventilation network. Key findings include:

(1) The ventilation network's sensitivity matrix and branch sensitivity reveal the most influential and affected branches, guiding ventilation system network optimization and adjustment.

(2) The Ventsim three-dimensional visualization model simulated and calculated the optimized and renovated scheme's ventilation effect, confirming the scheme's accuracy and feasibility, providing robust support for mine ventilation visualization management and optimization.

(3) Post-optimization, the total intake air volume rose by 34.65%, the air volume qualification rate reached 94.73% (a 31.4% increase), and the deep high-temperature mining area's total air volume increased by 43.62% compared to pre-optimization.

Reference

1. P.G. Ranjith, J. Zhao, M. Ju, R.V. Silva, T.D. Rathnaweera, A.K. Bandara.Opportunities and challenges in deep mining: a brief review, Engineering,2017,3 (4) :546-551
2. Xu G, Huang J, Nie B, Chalmers D, Yang Z. Calibration of mine ventilation network models using the non-linear optimization algorithm. Energies,2017,(11):131
3. Semin MA, Levin LY. Stability of air flows in mine ventilation networks. Process Safety and Environmental Protection. 2019,124:167-171
4. ZHONG Deyun,WANG Liguan, BI Lin, et al.Algorithm ofcomplex ventilation network solution based on circuit air—quantity method. Journal of the China Coal Society,2015,40 (2) : 365-370
5. Feng, S. C., & Fu, H.The optimal selection of air flow adjustment branch of mine ventilation network.Journal of Liaoning Technical University (Nat Sci Edi), 2019,38(6): 513-516
6. WEI Lian-jiang,WANG Yun-jia, FANG Zong-wu. Theory and Process to Simplify Complicated Ventilation Networks. Journal of China University of Mining & Technology,2010,39(4) :1000-196