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Ventilation system optimization of Shaxi Copper Mine based on Ventsim

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Abstract In view of the complex ventilation system of Shaxi Copper Mine, difficult ventilation in part of the midsection and low effective air volume, the route of measuring each midsection of the mine ventilation system was designed in advance, and then the measurement and analysis were carried out. The Ventsim three-dimensional model of the mine ventilation system was established, and three ventilation optimization schemes were proposed. The air network calculation of the three schemes was carried out by Ventsim. The results show that when two fans are added to the -705m section, one fan is added to the north wing of the -770m section, and the entrance of 800m ramp is closed, the total air volume of the -705m section is not only increased, but also the air volume of other sections is reasonably distributed. The measured air volume after the implementation of the scheme is basically consistent with the simulated air volume, which not only shows that the downhole parameters are set more accurately. It also lays a foundation for the later simulation of other directions.

Keywords Ventsim, Ventilation system, Effective air volume, Wind net solution, Optimization of ventilation

1 Introduction

The underground ventilation system is an important guarantee for the safe development of underground production activities. The quality of mine ventilation directly affects the working efficiency and physical and mental health of underground personnel [1]. Meanwhile, the ventilation system is also one of the main energy consumption units of underground metal mines and a key link in the process of mine production and operation to save energy and control costs. With the increasing mining depth of large-scale metal mines in our country, ventilation system has become more complex and ventilation problems have become more and more [2]. To improve production capacity and improve mining conditions, underground ventilation system should be actively improved [3].

Regarding the optimization of ventilation system, scholars at home and abroad have carried out various studies. Zhang Haiqing [4] et al measured and analyzed the ventilation resistance of Pingmei No. 8 Mine, combined with the long-term mining planning of the mine, put forward three ventilation optimization schemes, and then obtained the optimal scheme by using MVSS simulation solution. After measuring the ventilation resistance of Liangshuijing coal mine, Yang Haopeng [5] analyzed the problems existing in the ventilation system and analyzed, simulated and optimized the main problems existing in the system. Aiming at the current situation of the ventilation system of Wang Chao coal mine, Wang Wancai [6] determined the ventilation resistance after setting the measurement route, and put forward the optimization measures such as dressing the return air roadway and expanding the roadway, and achieved good results. Aiming at the change of ventilation mode in Micun Coal mine, Lu Zhongliang [7] measured the parameters of each component in the ventilation system, put forward an optimization scheme and used VENT software for simulation. Through optimization, all parameters of the ventilation system met the specified requirements. Yang Li [8] proposed to use FLUENT model to simulate the stope optimization scheme and reverse wind, and the simulation results proved that the ventilation optimization scheme could meet the requirements and be implemented. Lu Hui [9] used Ventsim to simulate six different optimization schemes for the island working face of Nanshan Coal mine, so as to determine the optimal scheme. Shen Yanyuan [10] used Ventsim software to simulate ventilation conditions in different stages and different production periods, so as to determine fan selection. Yuan Mingchang [11] used Ventsim software to simulate and compare different ventilation optimization schemes and determined the optimal scheme integrated from the aspects of economy and technology, so as to solve the problems existing in the ventilation system.

At present, the optimization of ventilation system is mainly based on downhole measurement analysis, and then simulation optimization, so as to determine the optimal scheme. However, the simulation optimization of ventilation system is mainly in coal mine, and there are few researches in metal mine. Ventsim 3D simulation software is the most widely used software with complete functions, simple operation [12] in the simulation software of ventilation system. Therefore, this paper decides to use Ventsim software for optimization combined with the actual situation of mine ventilation system.

2 General situation of Shaxi Copper Mine

2.1 Mine profile

Shaxi Copper Mine has 3.3 million tons of mining tasks each year, and about 24 stopes, which basically cross between the upper and lower middle sections, horizontal veins and river veins, and stopes. The air demand in each middle section changes dynamically, and the ventilation control task is heavy. The main ventilation structure is located on the return air side, which makes it difficult to dynamically control the ventilation structure because of the long walking distance.

Shaxi Copper Mine mainly adopts vertical shaft development, and the main development projects include auxiliary shaft, main shaft, air inlet shaft, south shaft and north shaft, as well as surface slope to assist the development. The main parameters of each development project are shown in Table 1.

Table 1: Main technical parameters of each development project

Project of development	Diameter of wellbore	Elevation	Note
During	Φ7.2	+29m～-1010m	Into the wind
Air inlet shaft	Φ6.0	+39m～-770m	Into the wind
Main shaft	Φ6.0	+31m～-970m	Into the wind
South air shaft	Φ7.0	+35m～-800m	Return air
North air shaft	Φ5.5	+48m～-770m	Return air

2.2 Ventilation system status

The ventilation system of Shaxi Copper Mine is a diagonal ventilation system with two wings, namely, the central auxiliary shaft, the inlet shaft and the south and north shaft. Fresh air flow required by ore body mining enters the middle part of each operation through auxiliary shaft, air inlet shaft and slope passage (auxiliary air inlet), etc. After cleaning the working face, it enters the south and north air shaft through return air passage and is discharged to the surface under the action of the main fan of the south and north air shaft return air.

At present, the main facilities of Shaxi Copper Mine are as follows: two ground aircraft stations, one south and one north wind shaft fan, using dual operation; There are 2 auxiliary fans in the -465m section and 2 auxiliary fans in the -585m section.

At present, Shaxi Copper Mine has formed relatively independent ventilation systems in the south and north wings of -410m, -530m, -650m, -705m, -770m and -800m sections. Multiple sections of -410m to -530m and -

650m to -770m have been excavated at the same time, and the ventilation system is relatively complicated. Problems such as difficult distribution of air volume according to demand, low effective air volume rate, air leakage, air pollution in series, air pollution circulation, air flow short circuit, etc., and with the increase of the mining middle section and the expansion of the scope, a more complex ventilation network will be formed, bringing many problems for mine ventilation.

Therefore, according to the actual situation of the mine, it is of great significance to build a reasonable and scientific ventilation mode to improve the underground working environment and reduce the occurrence of safety production accidents.

3 Determination of mine ventilation air volume

3.1 Determination of route and measuring point

Based on the operation plan of the mine and according to the normal production conditions of the mine, the main air flow road with large air volume and passing through the working face should be selected as the main measurement route and the rest as the auxiliary measurement route.

According to the specific conditions of the ventilation system of Shaxi Copper Mine, 16 main measuring routes and 3 auxiliary measuring routes are selected for air volume calculation. Among them, main measuring route 1 is the south wing mining area of the middle section of -410m, main measuring route 2 is the north wing mining area of the middle section of -410m, main measuring route 3 is the north wing mining area of the middle section of -465m, and main measuring route 4 is the south wing mining area of the middle section of -465m.Main surveying route 5 is the south wing mining area in the middle section of -530m, main surveying route 6 is the north wing mining area in the middle section of -530m, main surveying route 7 is the north wing mining area in the middle section of -585m, main surveying route 8 is the south wing mining area in the middle section of -585m, main surveying route 9 is the south wing mining area in the middle section of -650m, main surveying route 10 is the north wing mining area in the middle section of -650m.Main surveying route 11 is the north wing of the middle section of -705m; main surveying route 12 is the south wing of the middle section of -705m; main surveying route 13 is the south wing of the middle section of -770m; main surveying route 14 is the north wing of the middle section of -770m; main surveying route 15 is the south wing of the middle section of 800m; main surveying route 16 is the north wing of the middle section of -800m;The auxiliary test route is: 850m middle section, -910m middle section, 970m middle section.

After the measuring point is calibrated to the appropriate position of the shaft, the size of the shaft shaft area at the location of the measuring point is determined and the shaft shaft area is calculated. The sectional area is measured by the quadrulation formula of the average height of roadway multiplie
d by the width of roadway. The sectional area is calculated according to the following formula:

3.2 Determination Method

3.2.1 Determination of roadway sectional area

After the measuring point is calibrated to the appropriate position of the shaft, the size of the shaft shaft area at the location of the measuring point is determined and the shaft shaft area is calculated. The sectional area is measured by the quadrulation formula of the average height of roadway multiplied by the width of roadway. The sectional area is calculated according to the following formula:

$$S=B\,(H-0.07B) \qquad (1)$$

Where: B − average roadway width;

H − average height of roadway.

3.2.2 Measurement of wind speed (air volume)

The ventilation resistance tester was used to measure the wind speed of each roadway by the side measurement method, and the wind speed of each measuring point was measured by the wind meter. After the wind speed was measured by the wind meter, the wind speed correction curve was obtained according to the ventilation resistance tester (medium speed wind gauge No. 2636: V_{true} =0.98V_{meter} +0.12; Microvelocity speed wind gauge No. 295: V_{true} =0.388V_{table} +0.10; Microvelocity speed wind gauge No. 209: V_{true} =0.379 V_{table} +0.12;) Get the actual wind speed Vs after correction, and then calculate the actual wind speed V according to the following formula.

$$V=\frac{S-0.4}{S}V_S \quad (2)$$

Where: V − actual wind speed, m/s;

V_s − true wind speed measured on site, m/s;

S − roadway section area at wind point measurement;

0.4 − area of wind gauge to block airflow, m^2

According to the relation that the air volume is equal to the product of the actual average wind speed on the section and the sectional area, the actual air volume Q through each measuring point is calculated, and then the actual air volume value is converted into the air volume value Qc under the standard state according to the formula below.

$$Q_c=\frac{P_i(T_0+273)}{P_0(T_i+273)}Q=\frac{P_i(T_0+273)}{P_0(T_i+273)}Sv \quad (3)$$

Where: S − shaft roadway area, m^2;

v − Average wind speed in shaft lane, m/s.

Q_c − air volume under standard conditions, m^3/s;

Q − Air volume under measured conditions;

P_i − atmospheric pressure under measured conditions, kPa;

P_0 − atmospheric pressure under standard conditions, P0=101.325kPa;

T_i − Air temperature under measured conditions, ℃;

T_0 − Air temperature under standard conditions, T_0=20℃

3.3 Summary of measurement results of air volume in each middle section of mine

According to the pre-arranged route and measuring points, the group measurement was carried out, and the data of wind speed and cross-section of each measuring point were counted. The air volume of the main return air passage in each middle section was calculated, as shown in Table 2.

Table 2: Measured air volume in each middle section of mine

Location	North wing return wind (m^3/s)	South wing return wind (m^3/s)
-410 mid-section	57.8	51.3
-465 mid-section	35.12	41.6
-530 mid-section	60.2	49.7
-585 mid-section	40.1	31.3
-650 mid-section	38.2	70.3
-705 mid-section	8.8	41.6
-770 mid-section	17.4	56.6
-800 mid-section	24.6	33.8

4. Construction and verification of Ventsim ventilation system model

4.1 Introduction to Ventsim

Ventsim is a 3D simulation software developed by Australia. Its main functions include establishment of 3D mine model, calculation of wind network and dynamic simulation of ventilation system. Advanced simulation functions include thermal simulation, pollutant simulation, economic simulation, circulating wind simulation and other functions [13]. LiveView function can also be used to monitor the mine in real time [14]. The preliminary modeling of Ventsim is mainly built by importing 3D multi-segment lines in AutoCAD mine plan into Ventsim, and the coordinates of each point in the middle section can also be calculated, so as to build a 3D visualization model in Ventsim software [15].

4.2 Construction of Ventsim model of mine ventilation system

(1) Taking the layout of main shaft, auxiliary shaft, air inlet shaft, south wing return shaft, north wing return shaft and roadway in each section of the shaft of Shaxi Copper mine as the basic data of mine ventilation network, combined with the AutoCAD plan of each section of Shaxi Copper Mine, the three-dimensional AutoCAD multi-segment lines in each section were imported into Ventsim software to build the three-dimensional model of basic ventilation network of Shaxi Copper Mine;

(2) Based on the field measured data, modify the section size, shape, support form and other factors of the roadway and wellbore in the corresponding ventilation network, and set the friction coefficient of the roadway, whether the roadway is connected to the surface or whether the end of the roadway is closed according to the actual conditions of the mine;

(3) The speed, maximum power, diffuser diameter and other related parameters of various fans used in Shaxi Copper Mine as well as the corresponding fan characteristic curve of each fan are imported into the system, and the corresponding fan is set in the corresponding position of the model;

(4) Mark the location of slope passage, main shaft, auxiliary shaft, air inlet shaft, south shaft, north shaft, etc., and each middle section of Shaxi Copper Mine in Ventsim model for convenient observation. The Shaxi copper mine model is shown in Figure 1.

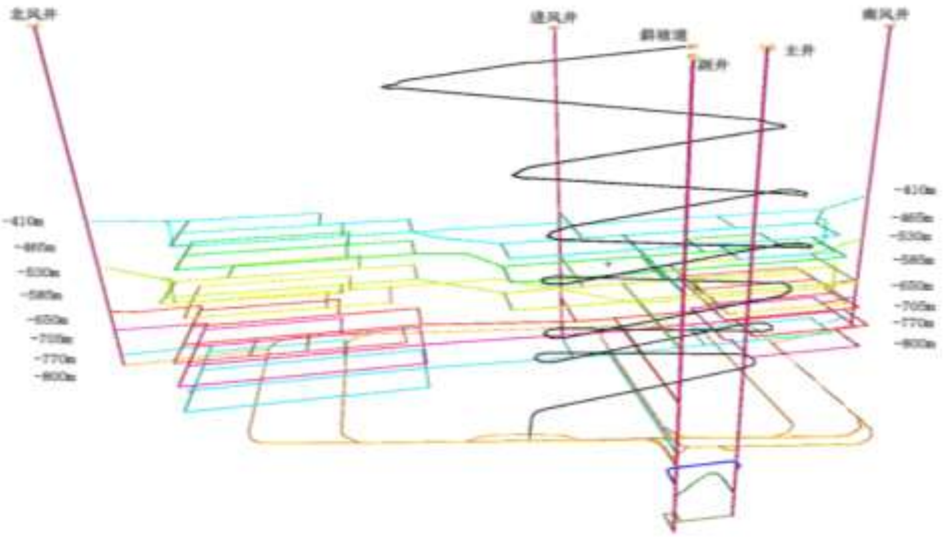

Figure 1: Ventsim 3D network model of Shaxi Copper Mine

4.3 Mine air volume simulation check

Through the simulation function of Ventsim air path, the built model was simulated, and the measured ventilation air volume results were compared with the simulated air volume results. It can be seen that the error between the simulated air volume and the measured air volume was within 5%, as shown in Table 3.

Table 3: Measured and simulated air volume

Location	**North wing return wind m^3/s**	**Simulate the north wing return wind m^3/s**	**Relative error**	**South wing return wind m^3/s**	**Simulate the south wing return wind m^3/s**	**Relative error**
-410 mid-section	57.8	56.4	2.42%	51.3	50.9	0.78%
-465 mid-section	35.12	34.7	1.20%	41.6	40.1	3.61%
-530 mid-section	60.2	59.4	1.33%	49.7	48.5	2.41%
-585 mid-section	40.1	39.2	2.24%	31.3	32.5	3.83%
-650 mid-section	38.2	37.8	1.05%	70.3	71.6	1.85%
-705 mid-section	8.8	8.9	1.14%	41.6	40.3	3.13%
-770 mid-section	17.4	18	3.45%	56.6	55.4	2.12%
-800 mid-section	24.6	25.6	4.07%	33.8	32.9	2.66%

5 Ventilation system optimization

5.1 Ventilation system optimization scheme

In view of the problems existing in the ventilation system of Shaxi Copper Mine, the following three optimization schemes are proposed:

Scheme 1: Add two fans in the middle of -705m.

Scheme 2: Add two fans in the middle of -705m and one fan in the north wing in the middle of -770m. Scheme 3: Add two fans in the middle of -705m and one fan in the north wing in the middle of -770m, and close the entrance of -800m ramp.

After the calculation with Ventsim software, the comparison table of air volume calculation before optimization and after optimization of the three schemes was obtained, as shown in Table 4.

Table 4: Comparison table of air volume calculation before optimization and after optimization of schemes 1, 2 and 3

Location	North wing return wind m^3/s	South wing return wind m^3/s	Solution 1		Solution 2		Solution 3	
			Optimized to simulate the north wing return wind m^3/s	Optimized to Simulate the south wing return wind m^3/s	Optimized to simulate the north wing return wind m^3/s	Optimized to Simulate the south wing return wind m^3/s	Optimized to simulate the north wing return wind m^3/s	Optimized to Simulate the south wing return wind m^3/s
-410mid-section	57.8	51.3	55.2	50.4	52.8	50.9	52.9	51.4
-465mid-section	35.12	41.6	34.5	40.3	34.3	40.3	34.3	40.2
-530mid-section	60.2	49.7	56.7	47.5	51.5	48.3	51.5	48.7
-585mid-section	40.1	31.3	38.7	32.2	38	32.2	37.8	32.1
-650mid-section	38.2	70.3	32.7	65	20.5	66.5	18.7	66.7
-705mid-section	8.8	41.6	36	55.3	33.5	55.3	32.8	55.1
-770mid-section	17.4	56.6	3.9	50.6	37.7	45.7	37.2	42.6
-800mid-section	24.6	33.8	22.5	31.7	10.2	33.1	16.2	34.7

5.2 Effect analysis of optimization scheme

By analyzing Table 4, we can see that: According to the measured data of the mine, the return air volume of the north wing of -705m is only 8.8m^3/s, and the total air volume of the middle section of -705m is only 50.4m^3/s, which cannot guarantee a comfortable underground working environment. Therefore, two fans are added in the middle section of -705m, respectively placed in the north wing return air lane of -705m and the south wing return air lane of -705m.This increased the air volume from 8.8m^3/s to 36.8m^3/s in the middle section of -705m, but also reduced the air volume of -770m north wing to 3.9m^3/s.

Therefore, in Scheme 2, based on scheme 1, a fan is added in the return air lane of the -770m north wing to increase the air volume of the -770m north wing, but it will lead to the reduction of the -800m air volume. Considering the underground measurement, it is found that the wind flow in the slope passage reverses to the middle part of 770.

Scheme 3 closes the -800m ramp crossing on the basis of Scheme 2, thereby increasing the air volume in the -800m middle section.

By comparison, scheme 3 not only increases the overall air volume of the -705m section, but also basically maintains the air volume of other sections. Therefore, the optimal scheme is to add two fans in the -705m section, add one fan in the north wing of the -770m section, and close the entrance of the -800m ramp.

5.3 Program implementation

After the construction scheme 3, the downhole measurement was conducted again. The comparison table of measured air volume before and after optimization and simulated air volume is shown in Table 5.

Table 5: Comparison table of measured air volume before optimization and after implementation of Scheme 3

Location	North wing return wind m^3/s	South wing return wind m^3/s	North wing return wind after optimization m^3/s	South wing return wind after optimization m^3/s	Optimized to simulate the north wing return wind m^3/s	Optimized to Simulate the south wing return wind m^3/s
-410mid-section	57.8	51.3	52.7	51.5	52.9	51.5
-465mid-section	35.12	41.6	34.2	40.1	34.3	40.1
-530mid-section	60.2	49.7	51.7	48.9	51.5	48.9
-585mid-section	40.1	31.3	37.5	31.6	37.8	31.6
-650mid-section	38.2	70.3	19.1	67.2	18.7	67.2
-705mid-section	8.8	41.6	32.3	54.7	32.8	54.7
-770mid-section	17.4	56.6	38.1	41.9	37.2	41.9
-800mid-section	24.6	33.8	18.3	34.6	16.2	34.6

By comparing the simulation solution in Table 5 with the air volume comparison table after the implementation of Scheme 3, it can be seen that scheme 3 has optimized the ventilation system at the present stage, increased the total air volume of the -705m section from 50.4m3/s to 87m3/s, and also made the air volume of the other sections be able to guarantee the basic downhole operations. The calculated results are basically consistent with the measured results. It shows that the parameters of the model built by Ventsim are basically consistent with the actual situation of the mine.

6 Conclusion

(1) Adding a fan to the north wing and south wing return air lane in the -705m section of Shaxi Copper Mine, adding a fan to the north wing in the -770m section of Shaxi Copper Mine, and closing the -800m ramp entrance can effectively solve the problems of ventilation difficulties and low effective air volume in the middle section, and improve the economy and safety of Shaxi Copper Mine.

(2) After the implementation of ventilation system adjustment and optimization measures, the total air volume in the middle section of -705m increased from 50.4m3/s to 87m3/s, which optimized the ventilation system and made the ventilation system of Shaxi Copper Mine more reasonable.

(3) The measured air volume after the implementation of the optimization scheme is basically consistent with the simulated air volume, which indicates that the underground parameter setting of Shaxi Copper Mine is reasonable and accurate, and provides a reference for the later simulation calculation of other directions.

(4) By using Ventsim 3D simulation software to simulate the ventilation system of Shaxi Copper Mine, the ventilation condition of the mine can be intuitively understood, so as to facilitate the adjustment and optimization analysis of the ventilation system of the mine.

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