Optimization and Reformation of Gas Drainage System Based on Emulation Technology

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Abstract: With the growth of the service life of mine and increasing of extending mining, underground operation requires more and more new drilling field of gas drainage. The increase of the length of drainage pipe causes rising of the resistance of gas flow and changes the reasonable resistance distribution of the initial drainage system, and it also affects the efficiency and reliability of gas drainage. In order to improve efficiency and reliability of the gas drainage system, it is necessary to optimize the pipeline system of gas drainage. The author considers the pipeline system as a directed graph, and analyzes the flow resistance of pipeline with the principle of ventilation network calculation. Combining with theconditions of Sihe mine, a comprehensive survey and test to the underground drainage system have been taken. It generates a diagram of pipeline system by mine ventilation simulation system (MVSS), calculates the maximum resistance of pipeline system in simulation module of gas drainage system, and finally proposes several schemes of optimization and reformation and solves several problems, such as local resistance is too large in drainage system. The research shows that drainage resistance is well-distributed after optimization and reformation, and the amount of gas drainage is increased, thus mine safety is greatly improved. Emulation technology introduces a new mean for information management in mine, and helps to control gas more effectively as well.

Keywords: gas drainage system; emulation technology; network optimization

1. Introduction

Gas control is the top priority of safety production in coal mine, and gas drainage is the fundamental measure of gas control. Gas drainage was promoted in high-gas mine and gas-outburst mine in 1950s, and the gas control policy of “draining before mining, output depends on air volume, monitoring and control” was proposed in 2002, raising the gas drainage effect has become the core of safety in coal mine. Although most mine have established underground gas-drainage system and ground gas-supply system, with the increase of extending mining and gas emission quantity, the pipeline system of gas drainage has become complex gradually, which has resulted in the increase difficulty in gas drainage. Studies on raising the effect of gas drainage usually focus on drainage methods, drainage technology, drilling, and drainage equipment, which has been unable to solve the new problems effectively in complex drainage system at present [1]. The theory of optimization in gas-drainage system obviously lagged behind current situation of gas-drainage. Some of coal mines have set up several drainage systems such as permanent ground pumping station, mobile underground pump station and fixed underground pump station, and they are working at the same time. Because the increase of the length of drainage pipe, the pipeline system of gas drainage become complex increasingly, and the initial drainage pipeline system no longer adapt to the new drainage work. The resistance distribution became unreasonable, which badly affects the efficiency and reliability of gas drainage system. So while gas drainage technologies are improving, optimum of gas drainage system should also be considered.

The optimization of gas-drainage system in existence focuses on the optimization of diameter after the confirmation of pipeline, so the studies are less in pipe network optimization. Some papersstudied grid connected and integrated of several drainage system, analyzed the change in pressure of drainage pipeline system before and after the grid connected, put forward a simple conclusion that grid connected should make the distribution of pipe resistance become more reasonable [2,3]. However, they didn’t do some intensive study on methods of pipe network optimization. And there are some other papers that used the grah theory to show the network chart of gas drainage system, and solved the problem that local resistance was too great in the drainage system[4]. This paper makes a study of optimum renovation of gas drainage system in Sihe mine based on emulation technology.

2. Current Situation of Gas Drainage in Sihe Mine

Sihe mine has built two temporary drainage stations respectively at the industrial square of west ventilation shaft and main inclined shaft in 1997, and set up five units of water-circulation vacuum pump of Type-SK-30. About 19 million Nm^3 gas had been extracted until May 2000. Afterwards, two fixed pump stations have been built in the industrial square of west ventilation shaft and underground of east-mine, so as to satisfy the need of production and life in Sihe mine. To end of January 2007, about 470 million Nm^3 gas had been extracted, and the gas drainage volume reached 139 million just in 2006. The gas drainage in Sihe mine had kept a certain scale.

The gas drainage system of Sihe mine has been used for many years, and the initial drainage pipelines have emerged some problems as follows: ① Because the mining depth and the length of drainage pipe have increased, it resulted in a growing drainage resistance, which has affected the efficiency of gas drainage; ②For the prolonged service of the pipeline, some of the pipes have become aging and rusty, leakage and deposition of water and coal, which have affected the efficiency of gas drainage; ③New drilling field of gas drainage is added, which changes the reasonable resistance distribution of the initial drainage system. So it is necessary to renovate the initial gas drainage system in Sihe mine, in order to improve the efficiency and reliability of gas drainage system and the safety in production.

3. Theory of Network Optimization and Regulation

3.1 Path Method

The path method in network optimization and regulation is a node-driven and depth-first search method by which all paths are found out, and the second resistance path is regulated based on the maximum resistance path[5]. After the regulation of the second resistance path, the paths which haven't been regulated should be reordered, after that they should be regulated again, and then the process continues until the path should no longer to regulate.

The total power dissipation of pipe network will be minimized, when there haven't any regulation facilities in the network and the air flow in pipeline distribute automatically. According to this axiom, the air flow should be distributed firstly in the sub-network(G'=G=E) which has removed the circuits of constant air volume, then the node of entire network G can fit the "air volume-balance law", but the circuit containing e'(e'∈E') maybe not fit the "air pressure balance law", namely the resistance of every path maybe not equal. In the no equilibrium state, the total power dissipation of pipe network and the maximum resistance are as (1) follows:

$$\begin{cases} N' = \sum_{i=1}^{n} r_i p_i^{\,3} \\ H_{\max} = \max\{H_p\} \end{cases} \tag{1}$$

Here the path of maximum resistance is Pmax, the product of the value of maximum resistance Hmax and total air volume is defined as the minimum power dissipation of pipe. The formula of minimum power dissipation of pipe and minimum regulation volume are as (2) follows:

$$\begin{cases} N_{\min} = H_{\max} Q_f \\ \Delta N = N_{\min} - N' \end{cases} \tag{2}$$

The essence of path method is finding the optimal regulation position and volume, and getting the minimum of regulation volume and the power dissipation of pipe.

3.2 Mine Ventilation Simulation System

Mine ventilation simulation system (MVSS) is developed by Liaoning Technical University, which could analyze problems in the ventilation system scientifically and accurately, and proposes the best solution to solve the problem. The MVSS could not only propose the solution of optimization and reformation of ventilation system quickly and effectively when the production systems changes, but also aid decision making during the catastrophic of mine. The network of present ventilation system and parameters of main tunnel (eg:windage, air volume, air pressure) can be known clearly by the simulation of MVSS, which creates conditions for the analysis of ventilation system, reformation and extension of ventilation system.

The paper uses the module of simulation of gas drainage system in MVSS, which adopt an algorithm of network flow distribution based on the node pressure and constant flux. The module achieves the simulation of flow and negative pressure in gas drainage. The air flow in tunnel and the flow of gas in pipeline both can be regarded as a pipe flow, so the network calculation of mine ventilation also applies to the flux calculation of drainage system. Because of the constant flux of drilling in gas drainage, the paper adopts constant-flux-mode to decide the flux of drilling. The side of gas drainage showed as a sink node in ventilation network. So the new algorithm of network flow distribution based on the node pressure can be used to indicate the pressure of gas drainage. The drilling of gas drainage is similar to a blind drift. The pipeline is similar to a tunnel, and the flow resistance of pipeline can be calculated. The pump station is similar to a main fan, and the characteristics of pump station can be derived (especially the curve of flow and negative pressure). After such equivalent transform, the network calculation can be used to solve the network flow distribution of gas drainage system, which helps to achieve the simulation of gas drainage system and then use the method of optimum renovation for ventilation system to renovate and optimizes the drainage system.

4. Simulation and Optimization of Gas Drainage System in Sihe Mine

4.1 Survey of Pipeline System

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To create simulation system of gas drainage pipeline in Sihe mine, the pipeline system should be surveyed. A comprehensive survey and test to the underground drainage system has been taken in Sihe mine, and the equipment is Type-WGC gas parameter tester of drainage pipe made in Chongqing Coal Academy of Science. The items of survey are as follows: topology(An important basis for simulation of pipeline system), name of the pipe(For pipe identification and inquiry), length of the pipe(Test point arrangement, calculation of resistance coefficient), diameter of the pipe(Calculation of resistance coefficient and flux), circumference of the pipe(Calculation of resistance coefficient), regulable(Network regulation), location, angle and the role of the gate valve(Analysis of reasonableness of the regulation in current pipeline system, find out the optimal position of regulation, volume of regulation, reliability, stability, resilience security of the piping system), coordinate of the gate valve(Find out pipe position in space). Some of the survey records and test parameters are as tab.1 and tab.2 follows:

Table 1. Survey of pipeline system(segment)

Type	Material	OD (mm)	ID (mm)	THK (mm)	single length (m)	Location and length of laying（m）			
377	Brazed tubes	377	350	13.5	6	*North air return way in East Area*	*East air return way*	*Second East air return way*	*Third East air return way*
						1000	1260	550	1650

Table 2. Test parameters of gas drainage system(segment)

Location	Time	Negative pressure (Kpa)	Concentration (%)	T (℃)	Mixing volume (m^3/min)	Purity contents (m^3/min)
Exit of 23054 tunnel at Second East Area	6.12	11.363	54.27	23.25	66.08	36.3
	6.17	11.433	51.22	20.46	66.04	33.827
Drainage conditions of Second East Area：	Last week	The average concentration is of 54.27 (%) at exit of every tunnel, The total drainage volume is of 36.3(m^3/min)				
	This week	The average concentration is of 51.22 (%) at exit of every tunnel, The total drainage volume is of 33.827(m^3/min)				

4.2 Simulation of Present System

The simulation documents should be created firstly. MVSS create the diagram of simulation by DXF File based on the original diagram of the gas drainage system. Then the pipeline in the diagram of simulation should be inspected and amended one by one, in accordance with the results of survey of pipeline system, in order to closely resemble the actual topology and status of the drainage system. Also the connectivity of the graph must be checked by designated function. If it pops a message box saying “It is a connected graph” when checking the connectivity of the simulation graph, this shows that the simulation graph is connected. The direction of flow in diagram is also need to be checked to ensure that it is stay the same with reality. Finally, the diagram of simulation of the pipeline system is being created, as is shown in the Fig.1.

It needs to complete the test data, for example, the calculation of frictional resistance and local resistance and so on, then assigns data for the node and pipeline in simulation system, and gives the error analysis. When the button 【Simulation of airflow distribution】 is clicked, it obtains the simulation results of pipeline system of gas drainage in Sihe mine at present. The simulation of negative pressure is 33.1Kpa after the simulation, but the actual test of negative pressure is 34.6Kpa in pump station, so the simulation error is 4.3%. The simulation of flux is 247.4m^3/min, which is nearly consistent with the actual. So the simulation system could used in optimization and reformation of drainage system in Sihe mine.

4.3 Renovation Plan of Pipeline System

The maximum resistance line of drainage piping system can be found out by the module of simulation of gas drainage system. After simulation and analysis, it shows that now the most serious problem of pipeline system of gas drainage in Sihe mine is:① The pipelines are so long, and the drainage resistance is too large. On the strength of drainage pump of the Second East Area, the negative pressure of the Third East Area is insufficient. And the maximum resistance pipeline is shown in the Fig.2 by the arrow. ② The drainage pipelines in DongJiao tunnel are too thin, and the drainage resistance reaches 33.0 Kpa , this is too large for the main drainage pipe.

According to the analysis of actual test data, the few gas drainage volume is due to the small energy of drainage pump and the large resistance of drainage pipeline. On the basis of actual situation and feasibility study, here gives two renovation plans:

(1) Part of the thin drainage pipes in East Area need to be replaced. Some of 200,250-Style pipes should be replaced by a larger diameter drainage pipe. Do the best to Maximize the diameter of main drainage pipe and branched pipe, and install automatic water distribution device in low-lying pipes; thereby this could reduce the

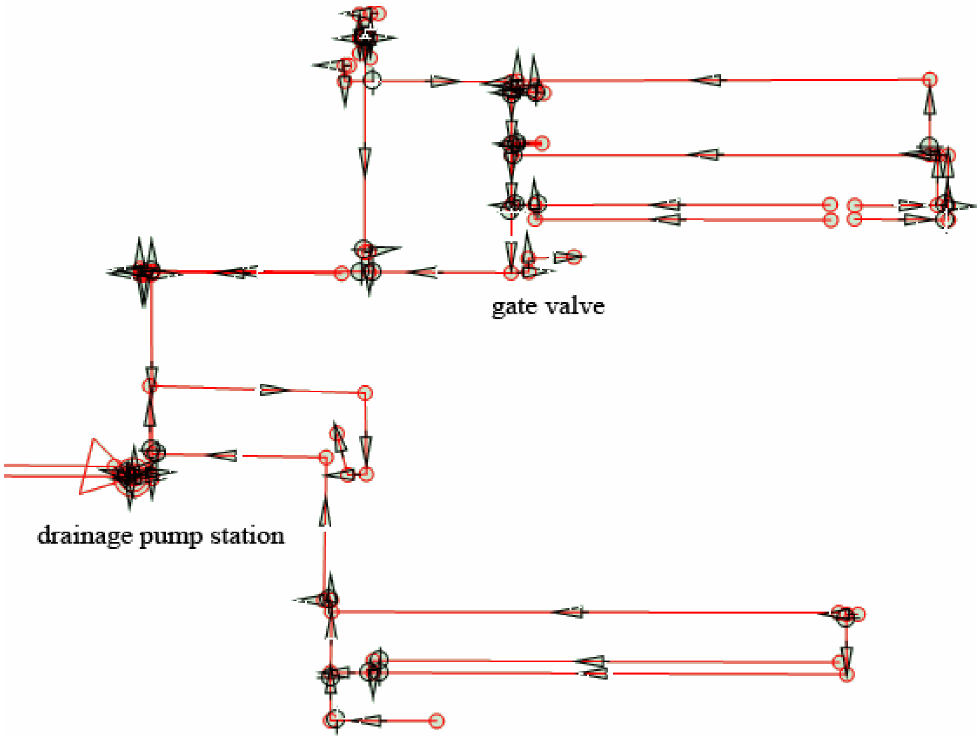

Figure 1. The diagram of simulation of drainage pipeline system in Sihe mine

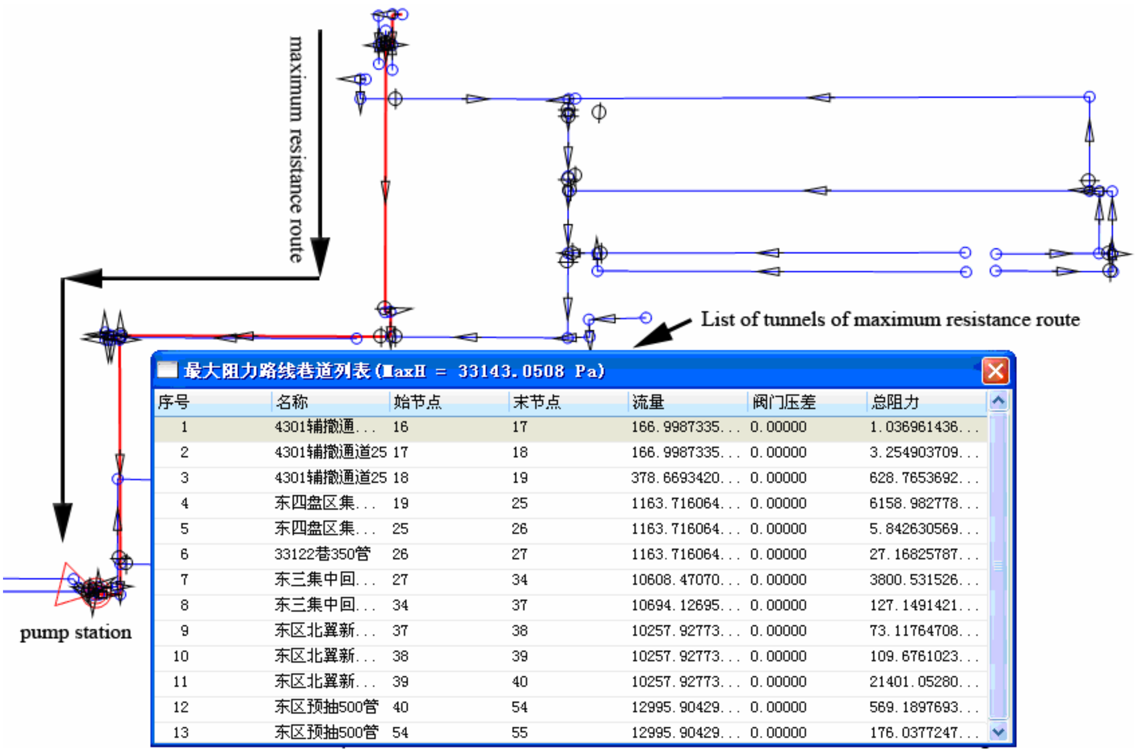

Figure 2. The diagram of maximum resistance route of pumping pipeline system

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on-way resistance of drainage pipe;

(2) A new drainage pump station should be built at XiaoDongshan, which could reduce the load on existing drainage pumping station in East Area consequently; besides, this could increase the negative pressure of drainage and drainage flux in Second East Area. Check the gas tightness of pipeline network and borehole underground, and timely close the air-leaked borehole, which can improve negative pressure of orifice of borehole.

In accordance with the above two renovation plans, the parameter of corresponding position of pipelines should be changed in the diagram of simulation system. Then the system should be simulated again after several changes, as is shown in the Fig.3.

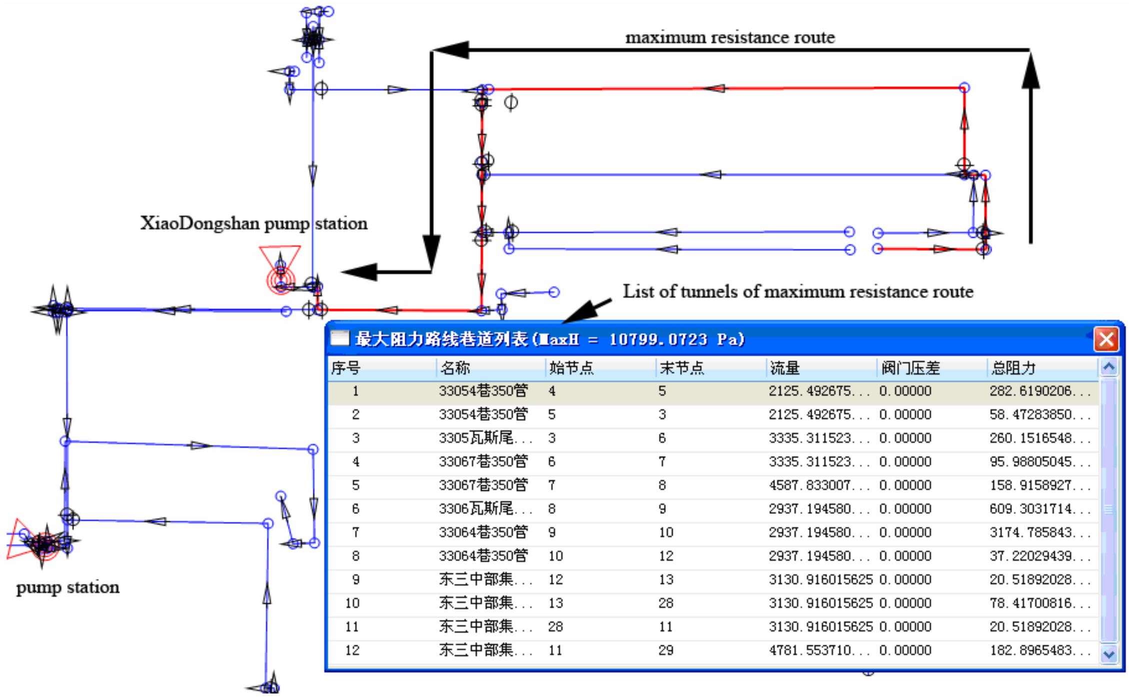

Figure 3. The resistance route diagram of Third East Area after when the XiaoDongshan pump station is built

After the analog simulation, it comes to a conclusion:

(1) The drainage task of Third East Area is primarily accomplished by the XiaoDongshan pump station after it has been built. The comparison of Fig.2 and Fig.3 shows that the maximum resistance route changes obviously, and the maximum resistance reduces to 10.8Kpa from 33.1Kpa, which is shown in the title bar of "List of tunnels of maximum resistance route" in Fig.3(MaxH=10799.0723 Pa). This greatly reduces the load on drainage pumping station, and lightens the burden on gas drainage of Second East Area as well.

(2) The negative pressure of drainage is increased in Second East Area, and the drainage flux is increased to 146.9 m^3/min after the renovation, which was about 40m^3/min at that time. This greatly improves the drainage rate in Second Eest Area.

(3) After the analog renovation of pipeline in Dong-Jiao tunnel, the pipe resistance reduces to the present 16.2Kpa from the former 33.0Kpa, and the flux is increased to 45.1 m^3/min from the former 32.2 m^3/min. It has a positive effect.

From the above, it is significant to optimize the present pipeline system of gas drainage in Sihe mine. By simulation of MVSS, it shows those two renovation plans are reasonable and successful for raising the effect of gas drainage.

5. Conclusion

The paper studies the optimum renovation of gas drainage system of Sihe mine by simulation system of mine ventilation, systematically analyzes the problems of drainage pipeline system emerged from Sihe mine, simulates the given renovation plan by the simulation system, and obtains good results. MVSS adopt the path method in network optimization and regulation, and an algorithm of network flow distribution based on the node pressure and constant flux, which explores the theory of optimization of gas-drainage system. Investigation should be periodically carried out on the drainage system in the high gas mine. They should timely find out problems, and simulate the renovation plan of drainage system by MVSS. This provides an important reference for raising the effect of gas drainage, also introduced a new mean for information management of mine.

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