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***Journal of Scientific and Engineering Research*, 2019, 6(5):110-114**

Review Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Research Status of Mine Ventilation System Optimization

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Abstract The research on mine ventilation system has been nearly 80 years old. Scholars and practitioners from all over the world have simple calculation tools, basic theory is not perfect, and ventilation problems are simple, and problems are encountered. The continuous popularization, the maturity of basic disciplines and the improvement of practical technology have made remarkable achievements in the optimization of mine ventilation systems. The mine ventilation system has undergone profound changes in many aspects, from empirical design to optimized design, from experience management to expert decision-support management, from basic theory to computer numerical simulation and adjustment optimization, from qualitative evaluation to quantitative evaluation analysis. It has become an extremely important branch of the mining safety field. At present, domestic and foreign experts and scholars in the field of mine ventilation system research mainly focus on: mine ventilation network solution, mine ventilation system simulation, mine ventilation system optimization and other aspects.

Keywords

1 Research Status of Mine Ventilation Network Solution

In 1854, JJ Atkinson's academic paper published by the Institute of Mining Engineers in Northern England was used as a mathematical model for solving the mine ventilation network; in 1925, the Polish H. Czeczott proposed the theory of the angular joint branch in the ventilation network. In 1928, the problem of ventilation network solving was proposed. In 1931, he first solved the θ-type ventilation network with angular joints by geometric method. In 1935, his compatriot S. Barczyk was used to solve nonlinear equations. Newton's method proposes a new approximate solution method, namely, the progressive method. With their joint efforts, the research on ventilation network solves the climax [1-2]; in 1951, Japan's Hiroyuki Hiroshi proposed a multivariate quadratic equation. In the same year, British DR Scott and FB Hinsley proposed a iterative calculation method. In 1953, the first computer was used to analyze the ventilation network, and the Taylor series approximation was proposed. The gradual calculation method, Scott-Hinsley, has basically matured the mathematical model of ventilation network solving [3]. Since then, scientists in Poland, the United States, Australia, Japan and other countries have continuously improved the mathematical model of the wind network solution in light of the convergence speed, topological relationship, and accuracy of the solution in the network solution [4].

China's research on the calculation of mine ventilation network originated from the 1980s. In 1984, Liu Fangxin [5-6] and others improved Scott-Hinsley, which not only improved the convergence speed, but also facilitated the calculation by computer; in 1986, Tian Conjia proposed the Scott-Hinsley complete solution for mine ventilation network. He used independent arguments as vectors to make the independent loops directional, and proposed the separation subgraph, the second matrix, and the convergence of the most independent loops. The new concept of sexual judgment criterion and convergence curve makes the adaptability and practicability of Scott-Hinsley algorithm enhanced. In 1989, Xie Xianping and others proposed to use the minimum energy principle of mine ventilation network to balance the wind network solution. The nonlinear programming problem in which the equation is equivalently transformed into an equivalent unconstrained optimization problem is finally solved by Newton's method. In 1990, Ma Xinxiao proposed using the Scott-Hinsley algorithm to solve the wind. When the net is used, if it is not converged because the initial value of the air volume is not suitable, it is only necessary to correct the wind volume of the tree in the loop while correcting the wind volume of the remaining tree string. Degree; in 1991, a new method for solving the wind pressure of ventilation network proposed by Chen et al. , and also used this method to prepare a node pressure analysis program for ventilation network adjustment optimization, and used it in actual mines; In 1994, Chen Haijun and others proposed a method to speed up the convergence speed and air volume correction of the Scott-Hinsley algorithm. In 2003, Wang Shugang used the air flow in the mine ventilation network as a non-compressible fluid. Steady flow, a unified mathematical model for the calculation of ventilation network during mine normal and catastrophic periods, although some simplifications, is very useful for a better understanding of the continuous changes in the normal ventilation and fire conditions of the mine; in 2004, Huang Guangqiu proposed a new method of full-loop regulation by correcting the shortcomings of the Scott-Hinsley method. The method theoretically considers the existence of fixed air volume branches in the ventilation network, which can realize the adjustment and on-demand of all circuits. Distribution of zero error; in 2005, Wang Gang and other methods for the generation of minimum spanning trees in the process of mine ventilation network solving using traditional "Based on the problem of long time calculation, the greedy algorithm is used to solve the ventilation network, which shortens the calculation time and improves the running speed of the program. In 2015, Zhong Deyun proposed an improved Scott-Hinsley. The algorithm adopts the loop air volume method without initial value, which is convenient for rapid secondary calculation. The BFS method is used to improve the structure of the spanning tree, and the double-path method is used to quickly circle the loop to realize the ventilation network under the fixed half-cut set. According to the need to separate the wind, the air volume can be automatically distributed on demand, and the problem of solving the ventilation network with one-way loop is solved. In 2016, Li Wei and other traditional network solutions are unable to cover the air volume change and air volume monitoring that lags behind the well. To all roadway problems, a real-time network solution method for mine ventilation is proposed: real-time monitoring data of wind volume is read, and based on this, the real-time air volume of other roadways is quickly solved during the inspection cycle of the monitoring system, and the blind spot of air volume monitoring is eliminated; 2018 Zhang Zhenguo proposed a new adaptive chaotic particle swarm optimization algorithm for the deficiency of traditional mine ventilation network solving algorithm. The minimum optimal power of the well ventilation network is the target to establish a nonlinear optimization mathematical model of the mine ventilation network. The penalty function method is used to transform the node air volume balance and the loop wind pressure balance equation into the penalty term in the objective function, and adaptive particle swarm optimization is adopted. The algorithm optimizes the objective function. When the optimization falls into the local optimum, the chaotic search is used to guide the particles to search again. In recent years, Chinese scholars have also proposed "rapid simulated annealing algorithm", "tunnel optimization mathematical model of mine ventilation network", "improved algorithm for wind flow control of mine ventilation system" and other mathematical models and methods that are easy to popularize and apply [7].

2. Status of simulation research on mine ventilation system

In 1946, the first electronic computer was born at the University of Pennsylvania. In 1958, Japanese scholar Has Himoto compiled a program that could solve up to 30 air duct networks. The research on ventilation network computing began [8]; in 1967, Wang and Hartman developed solutions to have natural ventilation and The program of the multi-fan three-dimensional mine ventilation network, the application program for solving the basic parameters of the mine ventilation system has also entered the mature and complete stage; with the improvement of the ventilation network solving theory, the mine ventilation simulation developed by various countries The software is also gradually commercialized, including VENTSIM and VentPC2003 developed in the United States, Vendis developed in France, VENTGRAPH developed in Poland, Ventsim and MicroMine developed in Australia, Datamine and VUMA developed in the UK, Ventsim developed in Japan, etc. [9], among them, the "VentPC2003" software developed by MVC Company of the United States supports DXF format files, the system can directly read AutoCAD graphic files, and the graphic display function distinguishes the inlet and return air states of the ventilation system by the unused colors, and the software A three-dimensional network diagram of ventilation can be established; the "VUMA" software developed by R. Burto and S. Bluhm of the United Kingdom, which is The user provides a display environment for two-dimensional and three-dimensional ventilation network diagrams. By simulating the flow state of the wind flow in the roadway, environmental parameters such as gas concentration, temperature, and dust can be directly displayed in the graph; developed by Professor W. Dziurzy'nski of Poland. "VENTGRAPH" software system, which is rich in functions, such as visual simulation, network diagram drawing, fire and escape simulation, roadway simulation, disaster and rescue training, safety monitoring, data processing and analysis, ventilation network and goaf simulation; "Ventsim" software developed by Chasm Company of Australia, which not only has three-dimensional multi-window graphic interface, but also can input and output various ventilation parameters conveniently and quickly. In terms of compatibility, it can directly convert the domestic mainstream design software AutoCAD DXF file into "Ventsim". The ventilation network model has the functions of ventilation cost and ventilation network economic optimization analysis, pollutant dynamic simulation, real-time monitoring, ventilation inspection file and other functions.

In the early 1990s, many universities and research institutes in China carried out a lot of research on ventilation simulation. In 1993, Liu Jian of Fuxin Mining College discussed the principle of computer automatic drawing of ventilation network diagram, procedures and procedures, and developed the "Mine Ventilation Simulation System" (MVSS) in 2000. The MVSS3D.NET version currently in use mainly includes: ventilation system network management, ventilation network solution and adjustment, ventilation system transformation simulation Four parts of the analysis and evaluation of ventilation system; in 1994, Huang Yuanping of Beijing Mining Institute and others proposed an computerized method for the total natural wind pressure of multiple air intake wells and multiple wind turbine mines, and developed " Mine fire disaster relief decision support system, the functions of the system include: automatic drawing of ventilation network system map, mine disaster simulation, k best disaster relief and disaster avoidance route selection; 2000, Beijing Institute of Technology Xie Xianping , etc. In view of mine ventilation design, the author puts forward the "Intelligent Mine Ventilation Design System" combining expert system technology and modeling optimization technology. The data management, graphics processing, design calculation, catastrophe process simulation, decision analysis and other functions of ventilation design are integrated. In 2003, Taiyuan University of Technology and Huatai University of Yantai jointly developed virtual reality using virtual reality technology. Mine Ventilation System, which not only realizes the full digitization of roadways and ventilation facilities, but also provides a good visual and interactive way to enable virtual people to “walk”, “observe” and “control” equipment in virtual roadways; Yuan Mei of Guizhou University and others used Visual Basic 6.0 as the programming language to compile the mine natural wind-child network computer program "MVNP" with various algorithms. The software only needs to input the wind network when solving the problem. The number of nodes, the number of branches, etc. to determine the basic characteristics of the wind network, can accurately and conveniently solve the wind network; in 2005, China University of Mining and Technology (Beijing) Du Xuesheng and others will geographic information system (GIS) and The vectorization concept was introduced into the mine ventilation to develop a Web GIS system, which can vectorize the mine ventilation system map to achieve ventilation information management and ventilation resistance measurement. Automation, and can also collect parameters such as downhole gas and dust in real time; in 2006, China University of Mining and Technology (Beijing) Han Wenzhao and others used virtual reality and GIS technology to develop a mine ventilation safety and security early warning simulation system. The system mainly includes: ventilation system analysis, ventilation system virtual scene, accident analysis and simulation three modules, not only can realize the three-dimensional reality of the roadway, but also display the parameters such as gas and wind speed in real time; in 2011, Jiangxi University of Technology Shen Shen et al. used the client and server architecture to design and develop "3DVS". The system uses SQL Server to build a database and manage roadway and wind path data. The user interface is developed with Visual Basic 6.0, and the ODBC technology is used. Database access, Frotran language is used to write wind network solver, mine ventilation network simulation is carried out under Solid Works 2006 software platform, and 3D solid graphics of wells are drawn.

3. Research Status of Mine Ventilation System Optimization

In 1930, Polish scholar A. Sałustowicz proposed the regulation of the resistance reduction of ventilation networks [10]; in 1936, American scholar H. Cross analyzed the flow, pressure, and friction by establishing a liquid flow model in the pipe network. In the relationship between the two, the general method of reducing the flow resistance of the incompressible medium is obtained. In 1956, the Polish H. Bystroń defined the angle-connected wind path from the relationship between the wind direction of the corner-connected roadway and the wind resistance of the adjacent wind path. The basic mathematical model of the mine ventilation network for the law of air balance, wind pressure balance and resistance law; in 1977, the United States M. Didyk [11] and others used PSU/MVS software to start mining in the new mine and the mine. The ventilation conditions after month, 24 months, and 36 months were evaluated, and software was used for optimization analysis to propose a method for improving the ventilation system. In 1989, Weimin Hu and others in the UK combined with the actual mine and used computer simulation to adopt The longest path algorithm to determine the optimal position and parameters of the ventilation system optimization adjustment facility, and introduces a new method to determine the pressure of the new fan; in 1992, the United States Wang Y. J and others This paper proposes a special cut set operation method and a solution to solve the problem of mine ventilation network using a mathematical plan, and analyzes the method of reducing the ventilation resistance of the mine by multi-fan combined operation mine; in 2015, India A. Manohar Rao et al. used the high-humidity heat and high gas environment of the Adriana coal mine as an example to use the 3D simulation software developed by the team to plan the location and operation mode of the artificial air cooling system in the underground, and to economically At the angle, the overall analysis was carried out. In 2015, Macedonian Vancho Adjiski and others used the FDS simulator to establish a three-dimensional simulation model of the mine. Through the combination of fire simulation and ventilation simulation, the best escape route for different fires was determined. In 2016, Germany's Ghassem Heidarinejad used fluid dynamics calculation method to assist the wind turbine as the research object, and discretized the mass, momentum and energy equations. , how can the auxiliary fan in different positions and different working modes help to improve? Mine ventilation environment. In addition, scholars from Canada, Japan, Australia and other countries have used the advanced software to conduct a large number of researches on roadway size optimization, automatic wind adjustment facilities, and intelligent system construction [12].

In 1986, Tan Guoyun used the FVP-77 program to debug the mine ventilation resistance, and analyzed the different ventilation reform schemes. It was concluded that the mine was changed from mixed ventilation to two-wing diagonal ventilation. It can make the underground wind flow more stable, the ventilation resistance is small, the mutual interference is weaker, and the electric energy can be saved. In 1993, Xie Ningfang gave the mathematical model of the optimal roadway section, resistance adjustment, fan optimization, etc. in the optimization of ventilation system. And summarized the experience of multi-stage station and centralized ventilation system optimization; in 1994, Li Shuting proposed a variety of optimization schemes for the problem of insufficient supply of air in the No.5 mining area of Xuzhuang Mine. From the perspective of economics, the best solution was obtained. In 1996, Chen Changhua and others used the path method to establish the optimal mathematical model, continuously adjust the roadway section to determine the optimal section size, and at the same time, proposed the total wind pressure of the new mine. In 1998, Wang Pinglong proposed five pairs of most mines based on the analysis and analysis of common problems such as low efficiency of the main fan of the mine and large resistance of the return air section. In 2001, when Cheng LH used the MFIRER software to optimize the mine ventilation system, the study of the tunnel temperature and wind speed showed that a “pull-on” ventilation model could be established. In the case of fire in mines, high-temperature airflow and smoke are effectively eliminated. In 2002, Wang Conglu described the mine ventilation system and its subsystems using the theory of dissipative structure in which the entropy value tends to decrease in an open system. In the mine ventilation system optimization and computer simulation; in 2003, Zhang Xinghua and so on for the large amount of gas emission from the Sihe coal mine, the multi-lane layout was carried out during the first working face mining, and different ventilation systems were tried one by one. The most reasonable ventilation system; in 2005, Cheng Lei and others carried out technical measurement on Hebi No. 4 Mine, using computer to solve wind network solutions for different optimization schemes, and proposed the best optimization plan from the perspective of input and income; Bufanchen used the mine ventilation simulation software to establish a mine visualization ventilation model, and accurately determined the transformation by setting different optimization parameters. In 2009, Xie Xianping used the Fibonacci method to determine the location and quantity of automatic monitoring points for mine ventilation, and simplified the arrangement of measuring points in the measurement of ventilation system; in 2012, Jiang Zhongan , etc. The mathematical model of wind network solution was constructed by the improved Scott-Hinsley algorithm, and three optimization adjustment schemes were solved by the model to achieve good ventilation effect. In 2013, Liu Yongxing used Venttim software to establish five tigers. The 3D visualization ventilation network model of the mountain coal mine analyzes the ventilation system through wind path simulation and dynamic simulation, and combines economic analysis to obtain the optimal transformation plan. In 2016, Wang Guangxin applied 3DVS simulation optimization software to optimize the program analysis. Then, according to the numerical theory of network ventilation calculation, the solution is analyzed and analyzed from the aspects of technology, safety and economy. In 2018, Zhu Xudong passed the field test and wind network solution, and selected by different The contact lane is added in the location, and the fan working condition and the location of the wind are analyzed to obtain the best optimization plan.

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