ISSN : 0974 - 7435 Volume 10 Issue 23

2014

BioTechnology

An Indian Journal

FULL PAPER

BTAIJ, 10(23), 2014 [14738-14744]

Research ventilation system based on special downhole mine

Shuangyue Liu, Guanzheng Song
Civil and Environmental Engineering School, University of Science and Technology, Beijing, 100083, (CHINA)

ABSTRACT

In order to improve the working environment inside the mine, to reduce the mine accident rates, this paper established a pipeline fluid models based on tunnel modeling theory. And on this basis, using CAD rendered 2D models of pipeline mechanical ventilation fluid field, using COMSOL Multiphysics simulated the model and solved the numerical value. In addition, this paper made in the implementation of the metal mine site piping mechanical ventilation system. The experimental results show that the content of harmful gases, dust particle inside the mine ventilation have been reduced very large. Except the reference point 5 the rest four points oxygen content have certain of ascension. This system improves the working environment inside the mine. Besides the outlet maximum speed of 11.6m/s, with digital simulation results obtained close to the pipe diameter is 1.06m, which is consistent with the actual situation.

KEYWORDS

Mine accidents; Fluid model; 2D model; COMSOL multiphysics; Dust particles.

© Trade Science Inc.

INTRODUCTION

During the twelfth five-year period, the national economy is in rapid development phase. The expansion of the second industry enterprises allows that the demand for mineral resources is increasing. Vast territory, rich mineral resources in China, at the present time, there are 181 species of the developed and utilization of minerals. The resources accounted for 12% of the world, which is an important part of the world coal industry[1]. Exploitation of mineral resources is a comprehensive technology industry, involving a wide range content of geological exploration, blasting, mining, transport, ventilation, safety, electromechanical, electric and environmental protection. With the continuous expansion of China's coal industry, coal mine safety has become more important. In China, the modern exploitation of underground resources are still mainly rely on manual operations in underground mines. But the factors such as the impact of natural and geographical conditions, space and place in mining activities are in the process of changing. Underground working environment and security situation is very complex, and some even very bad, whether it is the stability of enterprises producing or personal safety of the mine workers are under great threat[2]. Correspond with the title of China's coal mines powers, and mines in our country is relatively backward in terms of security. Unsound management way, the leakage of poisonous, harmful, flammable and explosive gases in mine and the damage of the surrounding environment constantly, resulting in mine the frequency of accidents is also growing fast, personnel, financial losses increasing. According to statistics of China's ministry of land and resources, in 2008, 2009, 2010, the mortality rate of million tons mine is 3.92,3.21 and 2.86, respectively. Easy to see that the mortality rate showed a decreasing form, but compared to other more developed countries, the Figure is still high. In recent years, not happened safety accident or the number of mines caused no deaths accounted for only less than 20%[3].

Mine accidents have occurred mainly three reasons. First, man-made and unsafe operation of machinery and equipment to work in an unsafe condition. Low professional quality underground workers, lack of knowledge acquired, individual personality differences may have resulted in the occurrence of mine accidents. Through vocational training, the training quality of mine workers can be improved. The incidence of man-made mine improper operation can have been controlled. Mine machine appears aging phenomenon, malfunctioning because of not in the timely replacement, which is not easily perceived. That is a a huge security risk. Second, the lack of man-machine combination surface. Most of the modern formal mine installed a relatively sound monitoring equipment, but underground tunnel interwoven distribution, monitoring equipment placed within the chaotic irregularity. A large amount of information transmitted back, many kinds of statistical information collected on the ground in terms of information officers are often more cumbersome and complex work. Such as there is alarm message with equipment, monitoring personnel need to find the appropriate location based on address information. Because of the huge amount of data, or even false alarm situation, making a dangerous situation can not be quickly found and positioned. This is caused by the combination of surface mining and human-computer interaction management levels not convenient enough. Third, coal seam and ventilation installation in china are poor, and gas disasters is serious. With the increase of mining depth and mining intensity deepened, the highlighting danger of gas is also increasing. At the same time, because of the changing scale mining, the difficulty of groundwater prevention is increasing. Small and medium enterprises in order to reduce expenditure cost mines, underground mine ventilation systems and drainage systems are not fully constructed, leave security hidden danger for underground construction workers[4]. For special minerals (limestone mine), the poor ventilation will increase the incidence of accidents. Therefore, a reasonable and timely exclude both ventilation inside the mine harmful gases (such as H2S, CO, etc.) to improve the working environment in the mine and reduce the accident rate. While it can provide air for the accident survivors, and increase the survival rate of accidents[5].

DUCT EXHAUST VENTILATION MODEL

Model building

Fluid physics model

This model is the basis of thermodynamic theory. That is gas state equation[6], which thinks that the tunnel gas need to meet gas state equation.

Where P is the tunnel atmospheric pressure (Pa). is air density(Kg/m^3). R is the constant(297). T is the air temperature(Kelvin temperature, K).

In order to simplify this model, tunnel pressure is constant. That is

where C is constant.

In addition, the ventilation tunnel is typically conducted at low speed. Gas flow rate is generally roadway 5-8m/s. Tunnel fluid can be regarded as the stability and incompressible fluid. That is:

In conclusion, tunnel fluid physics model can be summarized as follows:

1) Voltage-regulation, low-speed, incompressible.

2) comply with gas state equation, the law of conservation of energy, etc.

3) comply with Boussinesq assumption (density change is not significant, considering only the quality affect of gas energy, etc.).

Fluid control model

From fluid physics model introduction we can know that tunnel gases follow the control equations, namely: continuity equation, momentum equation and energy equations[7], as follows:

$$\begin{cases} \dfrac{\partial \rho \mathrm{U_i}}{\partial \mathrm{x_j}} = 0 \\ \dfrac{\partial \rho \mathrm{U_i}}{\partial t} + \dfrac{\partial \rho \mathrm{U_i} U_j}{\partial \mathrm{x_j}} = -\dfrac{\partial P}{\partial \mathrm{x_j}} + \dfrac{\partial}{\partial \mathrm{x_j}}(\mu(\dfrac{\partial \mathrm{U_i}}{\partial x_j} + \dfrac{\partial \mathrm{U_j}}{\partial x_i})) + \rho\beta g_i (T' - T) \\ \dfrac{\partial \rho H}{\partial t} + \dfrac{\partial \rho H \mathrm{U_j}}{\partial x_j} = \dfrac{\partial}{\partial \mathrm{x_j}}(\dfrac{\lambda}{c_P}\dfrac{\partial H}{\partial \mathrm{x_j}}) + S_H \end{cases} \quad (4)$$

Where x_i is a direction (x, y, z) in rectangular coordinate system. U_i is the gas velocity of x_i direction(which is a vector quantity). μ is the gas viscosity coefficient(pa.s).the thermal coefficient(1/K). g is gravitational acceleration. T' is preset temperature(K). S_H is heat source(W/m^2). H is the entropy of the air ratio(J/kg). λ is the thermal conductivity(W/m.k). C_P is the specific heat of air(J/kg.k).

The above three equations that explained the significance of the tunnel gas follow the continuity of gas mass, momentum conservation and energy conservation.

Turbulence model

The phenomenon of turbulence is the blocks adjacent which present a turbulent flow state. The gas flow velocity V, pressure P, temperature T and density will appear the corresponding randomness changes over time. Popular speak turbulence is a kind of irregular flow phenomenon.

In turbulence control, generally considered the continuity equation and the energy equation for fluid motion control, for incompressible air turbulence equations as follows:

$$\begin{cases} \dfrac{\partial \rho \mathrm{U_i}}{\partial \mathrm{x_i}} = 0 \\ \dfrac{\partial \rho \mathrm{U_i}}{\partial t} + \dfrac{\partial \rho \mathrm{U_i} U_j}{\partial \mathrm{x_j}} = \rho f_i - \dfrac{\partial P}{\partial \mathrm{x_i}} + \dfrac{\partial}{\partial \mathrm{x_j}}(\mu \dfrac{\partial \mathrm{U_i}}{\partial x_j}) + (-\dfrac{\partial(\overline{\rho \mathrm{U'_i} U'_j})}{\partial \mathrm{x_j}}) \end{cases} \quad (5)$$

For the turbulence model, there are currently more mature Baldwin-Lomax algebraic model, one-equation model, Wilcox Sk-model and Menter Sk-SST models, this research uses one-equation model, see literature[9].

Numerical fitting pipe exhaust ventilation model

For a model numerical solving process under the specific condition is compared commonly multifarious. In order to reduce the amount of research tasks, the paper selects COMSOL Multiphysics finite element analysis software to fit for mine tunnel fluid model under the special condition[8].

COMSOL Multiphysics finite element analysis software is a professional numerical analysis software, which is able to solve engineering problems of partial differential equations. For partial differential equations, it can be modeled, simulated and can also be fitted on partial differential equations numerically[9,10].

The process of COMSOL Multiphysics finite element analysis software for the numerical model solution is that create a geometric model (2D or 3D tunnel model). Then it needs to definite physical parameters, divide the finite element mesh, solve, the visual processor, topology optimization and parametric analysis.

When you want to solve the model constants and boundary conditions, which set the constants and boundary conditions as shown in TABLE 1 and TABLE 2.

TABLE 1 : Model constants set

constant name	constant value	unit	physical significance
V	3.5	m/s	fluid velocity
	1.8*10^{-5}	pa.s	viscosity coefficient
	1.25	Kg/m^3	fluid density

TABLE 2 : Model boundary conditions set

boundary type conditions	entrance velocity	exit pressure	tunnel wall viscidity
U	3.5m/s		0
P		-0.35Pa	0

The diameter ventiduct were taken as 0.75m, 1m, 1.25m, 1.5m, 1.75m, 2m, 2.25m, 2.5m. When the system is stable (taking Time = 100s), the simulation results are summarized in TABLE 3.

TABLE 3 : Stable export maximum velocity

pipe diameter(m)	exit maximum velocity(m/s)
0.75	11.271
1	10.063
1.25	8.796
1.5	7.710
1.75	6.637
2	5.564
2.25	4.357
2.5	3.014

From TABLE 3, when the other set of constants and boundary conditions don't change, the exit flow rate will decrease as the diameter increases.

Record diameter is 1m, the exit velocity of the fluid changes with time, the specific changes as shown in Figure 1.

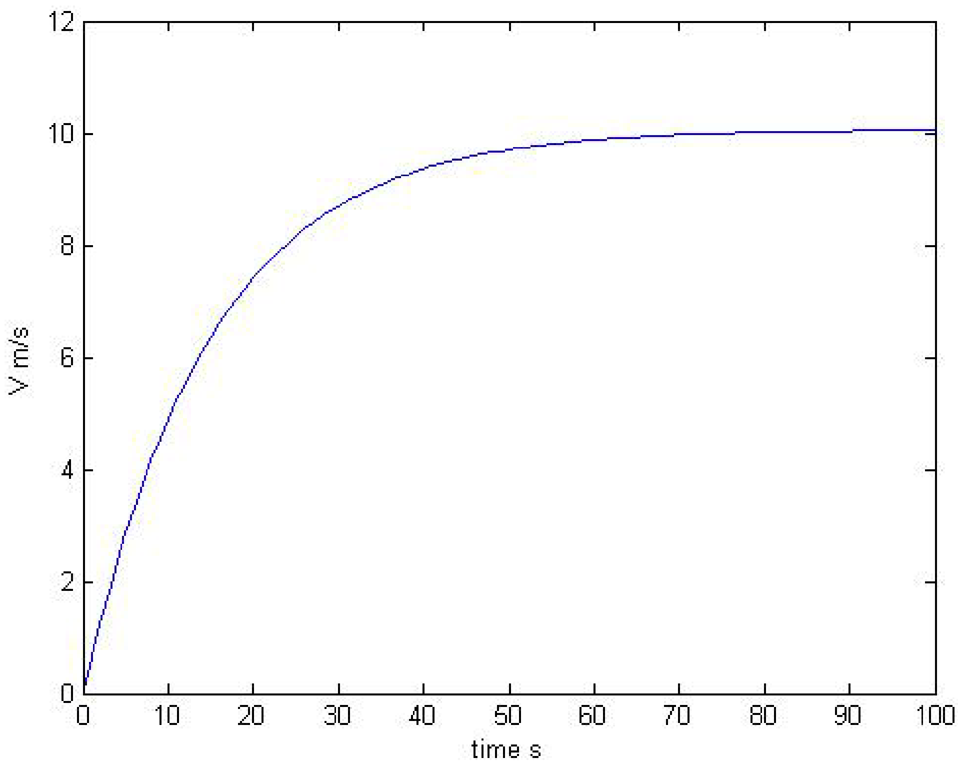

Figure 1 : Diameter-1m exit fluid velocity changes situation

Figure 1 is the time from 0-100s stope ventilation system of the exit fluid velocity changes situation. From the Figure shows that the exit fluid velocity increases with time gradually increases, and rises gradually reduced. When time = 60s, the fluid velocity is close to saturation(maximum state). While time = 100s, the maximum fluid velocity is 10.063m/s.

EXHAUST VENTILATION DUCT-SITE IMPLEMENTATION

This research is a joint project between schools and enterprises. In order to verify the feasibility of the model, the next presentation is conducted in a non-ferrous metal mines draw-out mechanical ventilation pipe experiments. Former mine site has a ventilation pipe that this research carries on the transformation, the establishment of pipeline draw-out mechanical ventilation pipe. Before the test, the mine contains toxic gases such as H_2S, CO, NO, gas and density of the larger dust particles should be tested.

For draw-out mine ventilation system, the air flow is air outside wells to main well (auxiliary well) to transport corridor to mine empty area to mine goaf gas mining Workspace to environment gas(toxic gases, mixed fluid and dust particles in the air) to branch pipes to head pipes to fan to floor. Draw-out mine mechanical ventilation system framework shown in Figure 2.

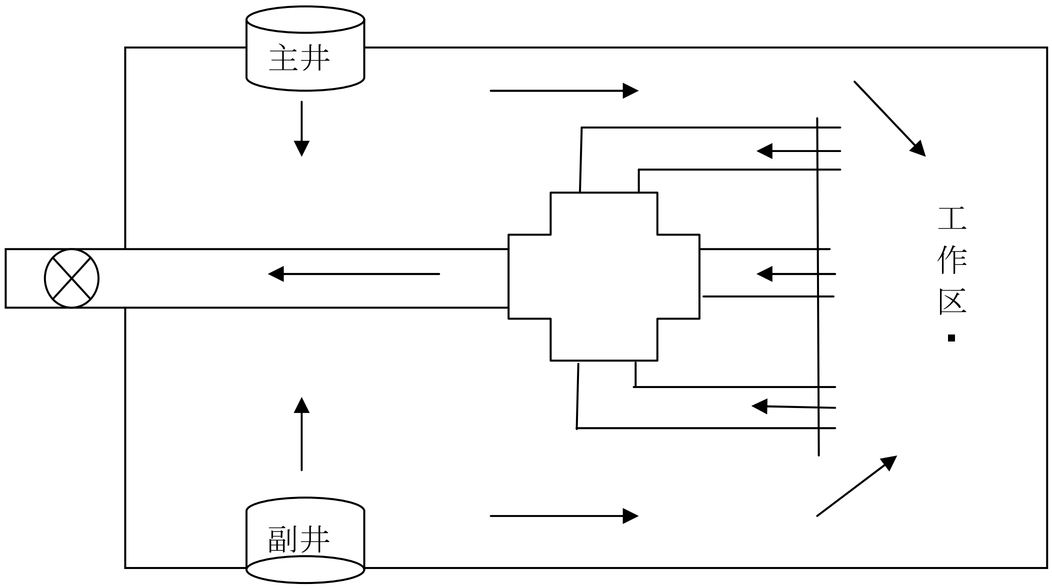

Figure 2 : Mechanical ventilation system block diagram; 主井-main well; 副井- auxiliary well; 工作区▪-workspace

Parameter set

1)The ventilation amount set. Ventilation amount is the sum of the employees in the oxygen consumption of the mine, blasting or mining machinery consumption and other consumption. To simplify the model, ventilation amount can follow once the largest number to go down when demand for air flow, calculated as follows:

(6)

Where Q is ventilation amount. 4 represents the amount of consumption of air per minute(m^3/min.person). N refers to a number of downhole(N = 140). K is a ventilation coefficient (depending on the circumstances of its vertical size can be mobilized, and generally 1.15).

2)Ventilation resistance. It refers to the fluid friction and local resistance. Mine tunnel ventilation resistance is calculated as follows.

(7)

Where H is tunnel resistance. a is resistance coefficient(related to the shape of tunnel, details are shown in TABLE 4). L is the length of the tunnel. U and U is the cross-section perimeter and perimeter. The meaning of Q see above.

TABLE 4 : The resistance coefficient lookup table

number	tunnel name	resistance coefficient a	number	tunnel name	resistance coefficient a
1	slope	0.035	3	working face	0.032
2	level	0.035	4	return air well	0.035

The selection of the fan

1) Fan flow. Fan flow is to measure the size of the fan drum wind capacity, it has also become air volume, and unit is m3/s. Computation formula is as follows

(8)

Each variable meaning see 2.1.

2)The fan negative pressure. The fan negative pressure formula is as follows

(9)

Where h is fan negative pressure. H is tunnel resistance. $H_{阻}$ is ventilator resistance. $h_{自}$ is natural wind resistance(This resistance can be positive or negative)

The pipe selection

The main parameters of the pipe selection is to determine the pipe diameter. When use pipe ventilation, the relationship between air flow and the pipe cross-sectional area and wind speed are as follows

(10)

Without loss of generality, this paper we consider the cross section of the pipe round selection (cross-sectional shape of the calculations for the other to follow this principle.

(11)

Where D is the pipe diameter, the formula (11) into formula (10):

Ventilation system test

1)Harmful gas measurement. Before measuring, the first should set the content of gas measurement. This paper main measurement of harmful gases, including gas operated(mainly methane), CO, H_2S and NO. The instrument used in this experiment to detect harmful gases is harmful gases analyzer detector alarm. It is needed to set the gas content, which can effectively detect a gas mixture content of gas operated, CO, H_2S, and NO.

2)Oxygen measurement. Measuring the oxygen content is mainly based on the principle of oxygen battery. The instrument used in this experiment to detect the oxygen is oxygen meter.

3)Dust particles measurement. The detection indicator of dust particles includes the number of particles per unit volume and the quality of particles per unit. The latter indicators were used in this paper. The dust is detected smaller than a diameter of dust particles suspended 75um particles (total dust) and a diameter less than 7um of respirable dust particles.

4)Wind velocity measurement. In order to test whether the ventilation system winds can meet mine ventilation requirements. This test focal point is located at the outlet and the outlet from the position of the five different reference points. Each test is in the wind flow field in mine stable conditions, to reduce the random error in the measurement. This research take average wind velocity for multiple readings.

RESULT AND ANALYSIS

Through the above analysis to 5 minutes after the bursting point as the reference point, the four detection results are summarized in TABLE 5 to TABLE 8.

TABLE 5 : Harmful gas measurement results

test points	CH_4	CO	H_2S	NO
before ventilate	15.4	37.0	20.1	11
after ventilate	0.2	0.01	0.02	0.00

TABLE 6 : Oxygen measurement results

test points	D1	D2	D3	D4	D5
before ventilate	20.1	20.0	20.9	20.5	20.3
after ventilate	20.3	20.2	20.9	20.6	20.2

TABLE 7 : Dust particle measurement results

test points	<75um dust particle	<7um dust particle
before ventilate	1231	8
after ventilate	41	0

TABLE 8 : Wind velocity measurement results

test points	V1	V2	V3	V4	V5	V6
air outlet	11.6	11.5	11.3	11.7	11.4	11.5
work point	11	7.4	4.5	3.2	2.1	1

For TABLE 5 to TABLE 7, ventilated before and after, all harmful gases have been greatly reduced, which is particularly evident decrease in NO, the average reduction rate up to 99.9%. Oxygen content except point 5 the rest have some upgrading. For dust particles, the total of dust particles reduce 97.8%. Respirable dust particles decrease to 0.

For TABLE 8, vents wind velocity is 11.6m/s, and the simulation results are close. The diameter of pipe was calculated that m, combined with the results of numerical simulation of 1m pipe diameter pipes is the best option.

DISCUSSION

This paper established a pipeline fluid models based on tunnel modeling theory. And on this basis, using CAD rendered 2D models of pipeline mechanical ventilation fluid field, and using COMSOL Multiphysics simulated the model, solved the numerical value.

Exhaust ventilation at the site of the pipeline implementation of our main tasks are:

First, analyzed the structure of the mine, and transformed the existing ventilation ducts, built pipelines draw-out mechanical ventilation ducts.

Second, analyzed the harmful gases, the concentration of dust particles in the original mine before the experiment, and analyzed the effectiveness of the ventilation system.

Third, according to mine the status quo(the number of working conditions) on the pipeline draw-out mechanical ventilation system design parameters, and selection for fan according to the parameters.

Fourth, the harmful gases, oxygen content, dust particles, and the wind velocity were measured around the pipe.

The field measurement data showed that the content of harmful gases, dust particle inside the mine ventilation have been reduced very large. Except the reference point 5 the rest four points oxygen content have certain of ascension that this system improves the working environment within the mine. Besides the outlet maximum speed of 11.6m/s, with digital simulation results obtained close to the pipe diameter is 1.06m, which is consistent with the actual situation.

REFERENCES

[1] Qiuyan Zhang; China mineral resources industry export-oriented development strategy research[D]. China University of Geosciences (Beijing), **(2003)**.

[2] Haifeng Wang, Yuanping Cheng, Qixiang Yu, Zongyong Zhou, Hongyong Liu; Coal and gas outburst coal mine safety research [J]. China University of Mining Journal, **37(2)**, 17-21 **(2008)**.

[3] Mingtang Lei,Xiaozhen Jiang, Li Yu; Model experiment of karst collapses[J]. Proceedings 7th International Congress of IAEG, **25(2)**, 211-217 **(1994)**.

[4] Xuerong Shang, Lili Shao; Mine is valued patients with severe multiple trauma emergency care [J] Chinese factories Medicine, **19(1)**, 45-49 **(2006)**.

[5] Jianbang He; The development of geographic information sharing policy proposals[A]. Chinese Association of Geographic Information Systems in mid-1999 Conference Proceedings [C], **(1999)**.

[6] Wenzhen Tao; Numerical heat transfer [M], Xi'an: Xi'an Tung University Press, **(2001)**.

[7] Qiuya Zheng; The research of complex numerical flow simulation accuracy and parallel computing based on Navier-stokes equations[D]. Xi'an Electronic Science and Technology University(Xi'an), **(2011)**.

[8] CnTechcomcn. Specialized numerical analysis system COMSOL Multiphysics [J]. CAD / CAM and manufacturing information, 40-44 **(2008)**.

[9] Lin Liang; The necessary tools of scientific research and numerical simulation of engineering- FEMLAB[J]. CAD / CAM and manufacturing information, 48-49 **(2004)**.

[10] Shanyang Wei, Kewei Ma, Bobo Li, et al; Based on COMSOL-Multiphysics of coal and gas outburst research[J]. **19(5)**, 14-16 **(2010)**.