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Experimental Study of Gas Emission, Distribution and Migration Rules in Mini Mine Ventilation Network

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Abstract -This article provides a CFD modeling study and a mini mine ventilation system experiments modeling test. The laboratorial model enables us to get an intuitive understanding of the construction of mine production system, the arrangement of roadway and the formation of goaf. First of all, the shift of different types of ventilation system can be achieved by opening and closing different valves of the simulation model, by which we are able to understand the relation between the arrangement of roadway and the types of ventilation systems. Besides, air distribution rules can be learned by adjusting the air quantity and measuring the air velocity in roadway. In addition, this model can be used to conduct the measurement of mine ventilation resistance. In addition, gas emission and extraction rules of goaf can be obtained by conducting gas concentration monitoring and detection, which provides an opportunity for us to master the usage of related experimental devices.

***Keywords*:** simulation experiments; mining education; gas emission; ventilation system

1. Introduction

Mine working face and goaf has always been the worst-hit area of gas disaster in mining industry (Sander & Connell, 2012). Key points of resolving this problem include determining the gas emission zone, implementing a reasonable gas drainage plan and constantly optimizing the ventilation system. The layout of gas drainage system is usually based on the gas drilling theory in the primary stage of coal mining (Karacana et al., 2011). But it is optimized constantly according to the variation of drilling hole, quality and quantity. Numerical simulation method is used to simulate mine ventilation network, but it is not easy for us to visually observe and understand the air movement in the ventilation system and goaf (SukSang et al., 2013). Therefore, the phase of the ventilation network planning itself may be assisted by the experimental verification of models at laboratory site.

2. CFD Numerical Simulation

Computational fluid dynamics, usually abbreviated as CFD, is a branch of fluid mechanics that uses numerical methods and algorithms to solve problems that involve fluid flows. Gas flow behavior in working face and goaf is a complicated process since numerous factors are involved (Xu et al., 2013).

2. 1. General Situation of the Mine

The studied coal mine contains 7 coal seams with an average thickness of 5.74m. Coal seam #10, with a high gas content (approximately up to 56.43m^3/t), has created severe difficulties in work safety and environment protection. Working face's length and strike length of coal seam #10 are 150m and 1500m. The U+L type ventilation system is adopted and longwall retreating extraction is used as the extracting method. Several gas drainage methods have been performed by studied coal mine in order to improve mine safety and develop production. However, the results of goaf gas drainage are far from satisfactory.

2. 2. Establishment of Numerical Simulation Model

The rule of gas emission basically depends on variation of crustal stress distribution caused by mining activities as it exerts an enormous influence on the variation of permeability of mined layers and adjacent layers. The distribution of goaf permeability can be obtained by analyzing crustal stress distribution of goaf and results of extensive previous studies. The variation of different areas may vary from 10^{-4} to 10^{-9} m^2. In this CFD simulation experiment, gas movement inside coal body, diffusive motion inside pore and gas adsorption process follow Darcy's and Hooke's law as well as the Langmui’s equation, while gas desorption process inside coal body is ignored. Working face and goaf are regarded as porous medium, gas is regarded as an ideal gas, and porous flow process is regarded as an isothermal process.

2. 3. Simulation Results

CFD models can be developed from the real mine layouts and its related parameters are shown in the Table 1. Air inlet boundary setting: VELOCITY-INLET; Air outlet boundary setting: OUTFLOW; boundary conditions obtained from field. According to the parameters and boundary conditions mentioned above, the simulation experiment based on U shape ventilation system is performed. The air velocity of inlet is 1.5 m/s, and the pressure of outlet is 90kPa. To facilitate the research, different cross-sections of goaf gas concentration distribution are selected with Z=0m (Working face floor), Z=7m (Working face roof), Z=15m (Caving zone), Z=30m (Fracture zone) and Z=50m (Bending Subsidence zone) in Fig.1.

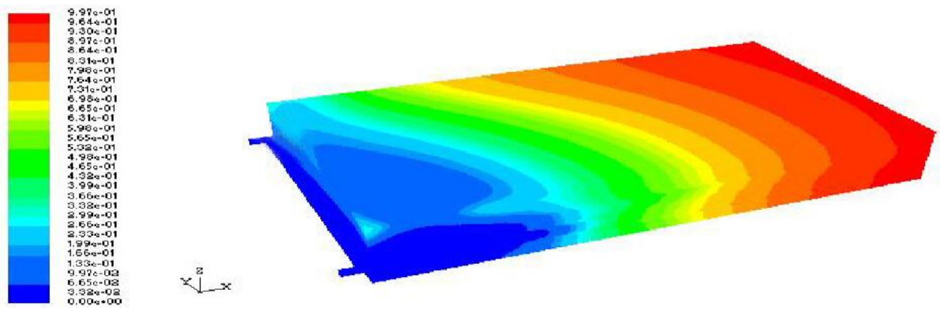

Fig. 1. goaf gas concentration distribution in three-dimensional

It can be seen from Fig.1 that the high concentrated gas moderately moves to the deeper goaf from the upper corner. Along the mining direction, gas concentration gradually increases from the working face to the deeper goaf, and then tends to be steady after a certain distance. Specifically, the goaf gas concentration in the range between 0m and 45m basically remains unchanged (lower than 6%) because of the air leakage effect and different pressure between the air inlet and outlet. It can be concluded that the most effective gas extraction spot constantly varies with the area where mining activities are performed. It is mainly located in the area of 40m-250m from the working face (along the horizontal mining direction, coal and rock separation area), 30m-40m from the floor (along the vertically direction, distressed and fracture zone), and approximately 60m-170m from the side of air outlet.

3. Laboratorial Simulation Experiments

Simulation is defined as the process of creating a model of an existing or proposed system in order to identify and understand those factors which control the system or to predict the future behavior of the system. Simulation can be used to show the eventual real effects of alternative conditions and courses of action. Simulation is used in many contexts, such as simulation of technology for performance optimization, safety engineering, testing, education and video games. Simulation can also be utilized for the ventilation system and optimization in the area of mining industry.

3. 1. Model Design

The similarity relationship between prototype and model is built according to the similarity criteria. The ventilation system model is proportional to the tunnel size of designated coal mine (1:50). For the purpose of the experiment feasibility, the model is simplified. The experiment model consists of five parts including model body (roadway, workface and goaf), fan and its affiliated device, gas drainage system, testing system and collection system, respectively (Fig. 2). Ventilation resistance in the model is approximately 3300 Pa, and the power is 9KW. Thus, a centrifugal fan is selected as the main ventilator of the model which includes inverted ventilation device, explosion-proof door, piping shock absorber and diffuser. The model is welded with steel plate and tube, covered by 8mm tempered glass. According to the mine pressure theory, different particle sizes of broken rock, coal and gangue are piled up in goaf to simulate the real situation of the work-site as much as possible. In order to simulate the distribution and movement rule of the working face and goaf, gas supply pipelines are paved at the bottom of the model.

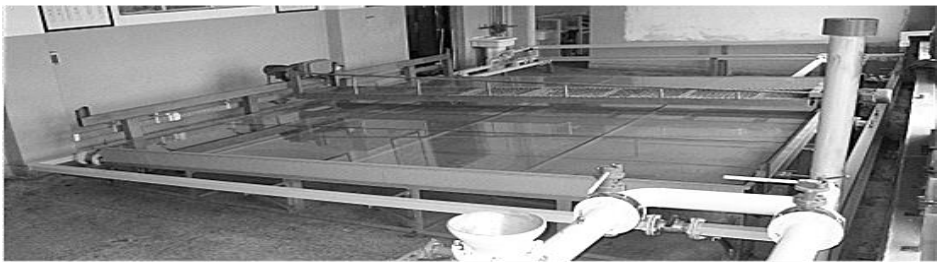

Fig. 2. Model body of simulation ventilation system

It can be clearly seen from Fig. 3 that the goaf are divided into 64 parts, and each part has a gas measurement point. Besides, two more points are selected in upper and lower corners. In addition, the transformation among different types of ventilation system and the adjustment of the air volume can be controlled by opening or closing the spherical valves.

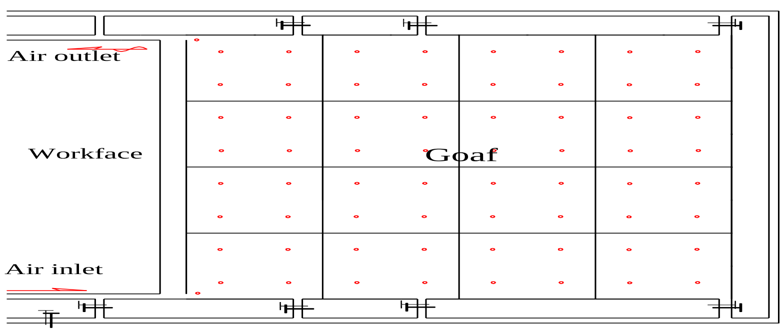

Fig. 3. the monitoring points in goaf

3. 2. Simulation Results

U+L-type ventilation system, consisting of two air inlets and one air outlet, accelerates the gas emission, diffusion and flow, balances the air pressure of upper corner, restrains the gas emission of upper corner, and compels the high-concentrated gas to flow over into the air outlet. Finally, it lowers the gas concentration of local areas, and effectively resolves the difficulties of gas over-limit of the working face. In addition, the total air volume in the working face has significantly increased as the fresh air is constantly offered from two air inlets.

The flow process of gas in U+L-type ventilation system is recorded in the simulation model, as is shown in Fig. 4. From the figure we can see that the high-concentrated gas moderately moves to the deeper goaf rather than gathering in the working face and upper corner.

Tab. 1 shows that the gas concentration of the air inlet is 2.99%. This indicates that high-concentrated gas not only gathers in the upper corner, but moves to the deeper goaf area as well, and it is able to be diluted by offering more fresh air from the two air inlets of U+L-type ventilation network. Besides, the gas concentration also gradually augments from the working face floor to the roof. Tab.1 also demonstrates the variation and the rule of gas flow and gas concentration in the U+L-type simulation system model. To be specific, the average gas concentration is around 6.91% (27cm from the working face and the upper corner), and it also rapidly rises to 30.65% when the measuring point is 135cm from the working face, then hovers at approximately 57.71% from 243cm 405cm.

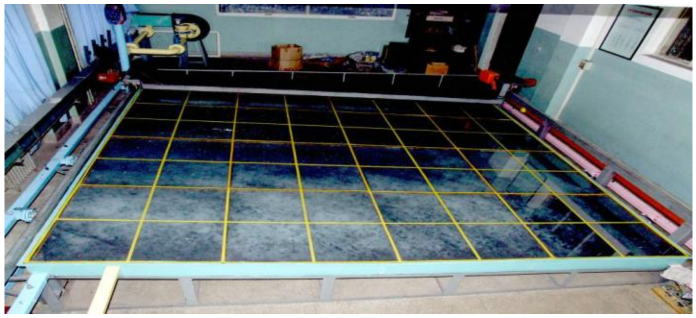

Fig. 4. U+L-type ventilation system (two air inlets and one air outlet)

Table. 1. Average gas concentration (%) in simulation goaf (U+L-type ventilation system)

	Distance from the working face/cm							
From air outlet/cm	27	81	135	189	243	297	351	405
26	4.24	6.16	33.39	42.16	64.12	66.53	68.26	69.52
78	9.16	12.67	36.93	57.84	63.87	64.76	67.14	68.61
130	11.25	11.81	32.11	52.38	61.89	63.22	64.15	65.08
182	10.19	10.76	27.39	51.91	59.15	62.35	63.71	63.17
234	8.34	10.31	33.67	55.99	57.62	62.68	62.96	62.15
286	5.97	10.12	29.88	41.38	54.78	60.61	61.33	61.07
338	3.13	10.94	27.46	36.22	50.87	54.91	57.76	59.39
390	2.99	9.52	24.39	35.87	49.38	53.19	57.16	58.84

4. Conclusions

The key points of resolving gas problem are exactly determining gas emission zone, implementing a reasonable gas drainage plan and constantly optimizing the ventilation system. In this study, both numerical simulation model and laboratorial experimental test model are established. Based on the results of numerical simulation and laboratorial test, it can be concluded that the most effective gas extraction spot constantly varies with the area where mining activities are performed. It mainly locates in coal and rock separation area of 27cm-243cm (between working face and deep goaf), 28cm-42cm (between the working face floor to the roof) and 78cm-182cm (between air inlet and air outlet).

References

Karacana, C. Ö., Ruizb, F. A., Cotè, M., & Phipps, S. (2011). Coal Mine Methane: A Review Of Capture And Utilization Practices With Benefits To Mining Safety And To Greenhouse Gas Reduction. *International Journal of Coal Geology*, 86(2–3), 121–156.

Xu, G., Luxbacher, K. D., Ragab, S., & Schafrik, S. (2013). Development Of A Remote Analysis Method For Underground Ventilation Systems Using Tracer Gas And CFD In A Simplified Laboratory Apparatus. *Tunnelling and Underground Space Technology*, 33, 1-11.

Sander, R., & Connell, L.D. (2012). Methodology For The Economic Assessment Of Enhanced Coal Mine Methane Drainage (ECMM) As A Fugitive Emissions Reduction Strategy. *International Journal of Greenhouse Gas Control*, 8, 34-44.

Kang, S.S., Datta-Gupta, A., & Lee, W. J. (2013). Impact Of Natural Fractures In Drainage Volume Calculations And Optimal Well Placement In Tight Gas Reservoirs. *Journal of Petroleum Science and Engineering*, 109, 206-216.