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Layout of buried pipe drainage in the goaf under Y-type ventilation

Y-type ventilation is commonly used in coal mines of many countries in recent years. Due to the lack of leakage airflow return roadway in the deep part of the goaf under Y-type ventilation, gas with high concentration would appear behind the hydraulic supports, which is easily to cause gas overrun accidents. Drainage pipes buried inside the goaf-side roadway retained can change the flow filed in the goaf and is commonly used to reduce the danger of gas overrun behind the hydraulic supports of the workface with a high gas emission. Based on the engineering practice of Xingwu coal mine in China, Fluent numerical simulation software was used to determine the reasonable mixed gas drainage volume of drainage pipes buried inside the goaf-side roadway retained. Then, taking into account the use of a single drainage pipe required larger diameter, and easy deformation, affecting the gas drainage effect; three drainage pipes instead of a single drainage pipe are arranged into the goaf-side roadway retained. Finally, through the field test, the rationality of the gas drainage volume and the layout of drainage pipes being selected are verified.

Keywords: *Y-type ventilation; gas overrun; gas drainage; numerical simulation.*

1. Introduction

Mine ventilation is critical to ensure the safety in mining of coal mine. At present, the main ventilations are used as U-type ventilation, U+L-type ventilation and Y-type ventilation (Yuan et al., 2006; Guo et al., 2012; Chen et al., 2014; Chen et al., 2016). For high-gas coal mines, Y-type ventilation is commonly used in many countries in recent years (Qin et al., 2015; Qu et al., 2016). In the Y-type ventilation, the return airflow roadway would be maintained by filling the roadway along the goaf. Also, the non mining areas of the workface are made up of two intake airflow roadway and the goaf-side roadway retained is the return airflow roadway. Due to the lower project volume of roadway excavation and less pillar loss, Y type ventilation can not only relieve the supersede tension of workface, but also greatly save valuable coal resources.

Many scholars have studied the related scientific problems about Y type ventilation. Haake et al. (1985) investigated the gas emission and ventilation in a workface with Y-type ventilation on the return side. Lu et al. (2013) analyzed the gas delivery law of goaf in Y-type ventilation workface and provided that high position drilling, ground wells and underground pipe extraction in the goaf should be used together to drainage the gas in goaf. Yang et al. (2014) optimized the ventilation of system of Huoerxinhe company and analyzed the advantages of Y-type ventilation. Qian et al. (2015) introduced the application of Y-type ventilation (goaf-side roadway retained without coal pillar) in deep longwall face and analyzed the influence of filling wall width on the stability of goaf-side roadway retained. Zhang et al. (2016) studied the overlying strata movements and stability control of the retained goaf-side in Y-type ventilation workface.

According to the previous literatures, although scholars studied the gas distribution law of goaf, overlying strata movements, etc. under Y-ventilation condition, the research on optimal layout of drainage pipes buried inside the goaf-side roadway retained is less. Based on the engineering practice of Xingwu coal mine in China, this paper analyzes the reasonable mixed volume for gas drainage and layout of drainage pipes in the goaf by using Fluent numerical simulation software and engineering verification. Reasonable mixed volume for gas drainage and layout of drainage pipes in the goaf can reduce the danger of gas overrun behind the hydraulic supports of the workface with a high gas emission under Y-type ventilation.

2. Research background

Research background of this paper is based on the engineering practice of Xingwu coal mine in Shanxi province, China. Xingwu coal mine belonged to high-gas mine. At present, No. 4 coal seam is being mined and the histogram of strata is shown in Fig.1. Experimental workface is called 42207 workface and its maximum gas content is 9m^3/t. The layout of

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Strata	Column	Min-Max/Average Thickness	Coal-rock name
Shanxi Formation, Permian		2.20-20.70/7.74	Mudstone
		0-5.00/2.70	Fine sandstone
		0-10.76/5.67	Mudstone
		0-0.79/0.60	Coal seam #2
		2.00-8.70/4.76	Mudstone
		0-0.82/0.57	Coal seam #3
		0-10.88/5.58	Sandy mudstone, Mudstone
		0-16.00/10.07	Mudstone, Medium sandstone
		0-1.20/0.82	Coal seam #4up
		0-3.60/2.07	Mudstone
		2.15-4.22/3.94	Coal seam #4
		0-5.50/2.92	Fine sandstone
		2.15-7.80/4.09	Mudstone
		0.45-1.90/1.24	Coal seam #5
		0-7.00/3.41	Mudstone
		0-58.85/4.33	Middle-fine sandstone

Fig.1 Histogram of strata

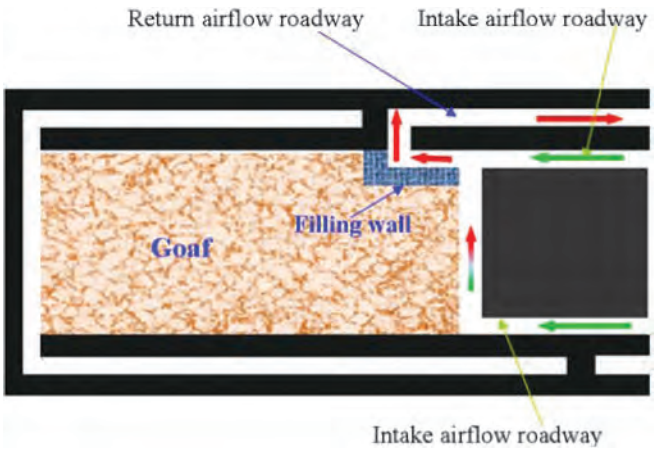


Fig.2 Layout of 42207 workface

42207 workface is shown in Fig.2. The maximum gas emission of 42207 workface is 70m^3/min, which is a very big value. The gas emission of 42207 workface is dominated by the mining coal seam and supplemented by the adjacent coal seams. Also, gas emission in the mining coal seam and adjacent coal seams accounts for 56% and 44%, respectively.

42207 workface belongs to the Y-type ventilation. Due to the lack of leakage airflow return roadway in the deep part of the goaf under Y-type ventilation, gas with high concentration would appear behind the hydraulic supports. In fact, during mining the 42207 workface, gas overrun behind the hydraulic supports occur frequently. Drainage pipes buried inside the goaf-side roadway retained was used to avoid gas overrun behind the hydraulic supports. However, the reasonable mixed volume for gas drainage and layout of drainage pipes in the goaf need to be studied.

3. Influence of mixed volume for gas drainge and layout of drainage pipes on gas distribution in goaf

Fluent software was used to simulate the gas distribution characteristics of goafs with different extraction volumes and different layout of buried pipes, so as to determine reasonable drainage volume of mixed gas and layout mode of buried pipes in goaf.

3.1 Model assumptions

Research works would be done by the following assumptions:

(1) Mining coal seam and adjacent coal seams are all uniform continuous.

(2) Gas in the goaf is considered approximately to be not compressed.

(3) Chemical reaction of coal and oxygen and heat transfer effects is not considered.

(4) Permeability coefficient of deep goaf is less than that of nearby the workface and the permeability distribution in goaf.

(5) Airs inside intake airflow roadway are only oxygen, nitrogen and no gas.

3.2 Model establishment

According to the measured data in Xingwu coal mine, the heights of caving zone and fissure zone are both 15m. Therefore, the height of the Z direction is 30m during the establishment of the numerical model. The length and width of the model are respectively 200m and 170m. Mining height of 42207 workface is 3m. Combined with field measurements, wind speed of intake airflow roadway is 2.36m/s and 0.98m/s, also, wind speed of return airflow roadway is 3.19m/s. as shown in Fig.3, the number of grids is about 1021860 and all the parts are divided into hexahedron grids. In addition, taking

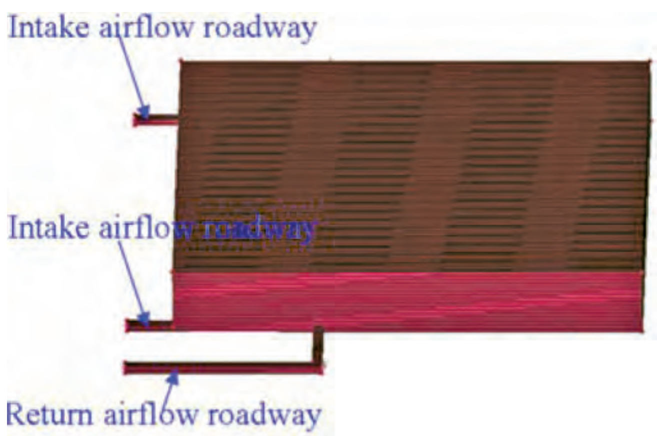


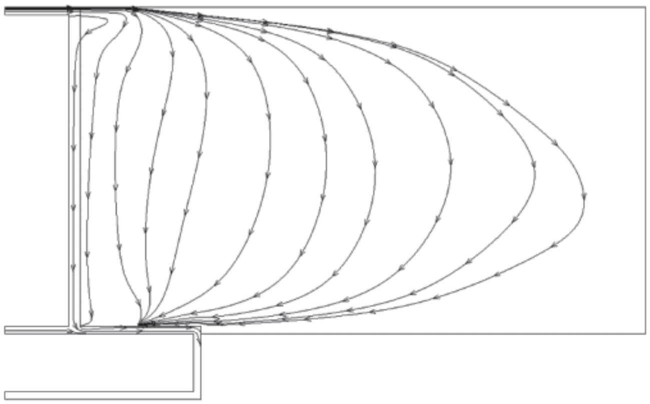
Fig.3 Model

the actual situation of Xingwu coal mine, a drainage pipe with 30m away from the open-off cut is buried inside the goaf-side roadway retained during establishing the model.

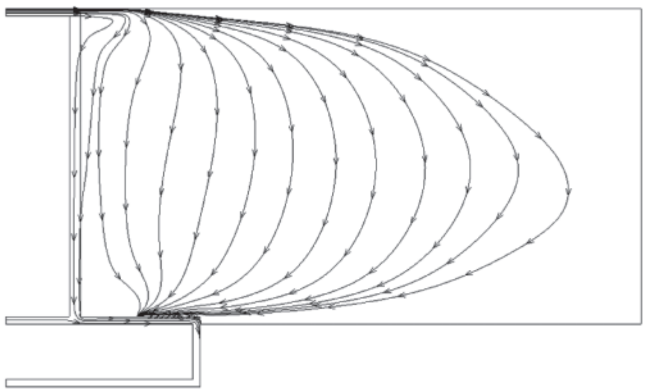
3.3 Influence of the mixed volume for gas drainge on gas distribution in goaf

3.3.1 Flow field in the goaf

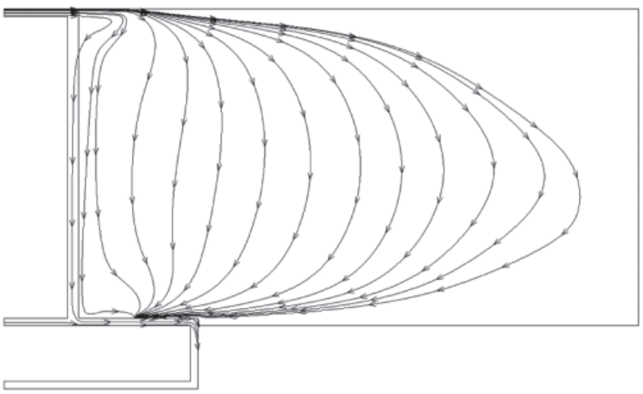
During the numeral calculations, the mixed volume for gas drainage of drainage pipe is set as 100m^3/min, 200m^3/min and 300m^3/min, respectively. The flow field in the goaf under different mixed volume for gas drainage is shown in Fig.4.



(a) The mixed volume for gas drainage of drainage pipe is 100 m^3/min



(b) The mixed volume for gas drainage of drainage pipe is 200 m^3/min



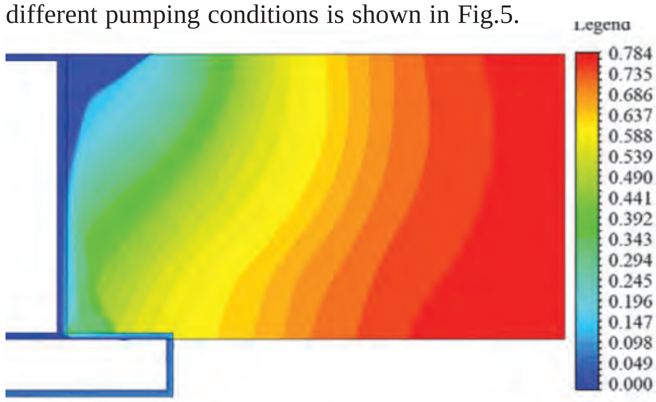
(c) The mixed volume for gas drainage of drainage pipe is 300 m^3/min

Fig.4 Flow field with 2m away from the floor of coal seam

With the increase of the mixed volume for gas drainage, the influence of gas drainage on the flow field in the goaf becomes more obvious. When the mixed volume for gas drainage reaches 300m^3/min, the airflow in the upper corner is affected by the gas drainage and the flow direction changes. The airflow leakage is flowing out of the goaf through the extraction system. Therefore, the mixed volume for gas drainage in the goaf should reach 300m^3/min.

3.3.2 Gas concentration in the goaf

The change of the flow field in the goaf will have a great influence on the gas distribution. According to the numerical calculations, gas concentration distribution in the goaf under different pumping conditions is shown in Fig.5.



(a) The mixed volume for gas drainage of drainage pipe is 100 m^3/min

(b) The mixed volume for gas drainage of drainage pipe is 200 m^3/min

(c) The mixed volume for gas drainage of drainage pipe is 300 m^3/min

Fig.5 Gas concentration distribution in the goaf with 2m away from the floor of coal seam

With the increase of the mixed volume for gas drainage, the high-concentration gas in the goaf will move backward. When the mixed volume for gas drainage reaches 300m^3/min, the upper corner gas has obvious movement to the outlet direction and the concentration contour line is backwardly offset in the range of about 30 m near the return airflow roadway, which is favourable for improving the gas treatment condition in the upper corner. Therefore, the mixed volume for gas drainage in the goaf should reach 300m^3/min.

3.4 Influence of the layout of drainage pipes on gas distribution in the goaf

With the increase of the distance between the drainage pipes and the workface, the influence on the flow field in the goaf near the workface will inevitably decrease.

Relationship between the mixed volume for gas drainage and drainage pipe diameter obeys equation 1.

$$D = 0.1457\sqrt{\frac{Q}{V}} \qquad \text{...} \qquad (1)$$

where D is the drainage pipe diameter, m; Q is the mixed volume for gas drainage, m^3/min; V is the gas flow rate in the drainage pipe, V = 10~15m/s.

According to equation 1, the inner diameter of the drainage pipe can be calculated. Taking V = 15m/s, when the mixed volume for gas drainage in the goaf reaches 300 m^3/min, the inner diameter of the drainage pipe is more than 652mm. The larger is the diameter of the gas drainage pipe, greater is the deformation after the roof collapsed, which would affect the gas drainage effect. Therefore, it can be considered that gas drainage in the goaf should be arranged to be co-extracted by multiple drainage pipes, which can more uniformly affect the flow field in the goaf near the workface.

In order to analyze the effect of co-extraction by multiple drainage pipes, three drainage pipes were arranged at 18m, 30m and 42m inside the goaf-side roadway retained behind the workface, whose total volume for gas drainage reaches is 300m^3/min and each drainage pipe has a mixed extraction volume of 100m^3/min. The flow field in the goaf is shown in Fig.6. Compared to Fig.4, the change of the drainage pipe layout has little effect on the flow field of large area in the goaf, but it has an impact on the upper corner flow field of the working face. The air leakage near the upper corner of the workface can go out of the goaf through the drainage pipe within a short distance.

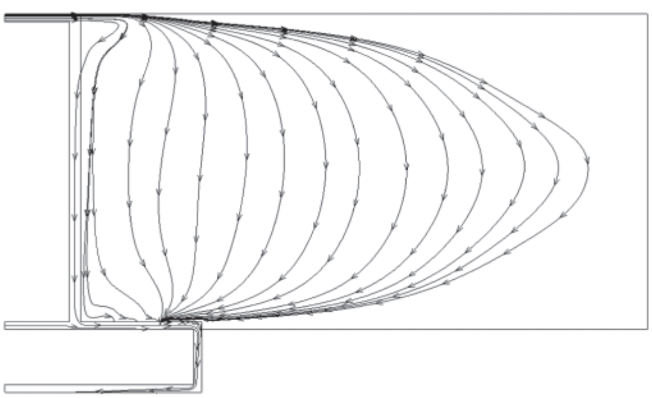


Fig.6 Flow field with 2m away from the floor of coal seam by multiple drainage pipes

It can also be seen from Fig.7 that the change of drainage pipe arrangement has a great influence on the gas distribution on the upper corner. Co-extraction arrangement by multiple drainage pipes can greatly reduce the danger of gas overrun on the upper corner of the workface.

Fig.7 Gas concentration distribution in the goaf with 2m away from the floor of coal seam by multiple drainage pipes

4. Engineering verification

According to section 3, during the engineering application, three drainage pipes were arranged at 18m, 30m and 42m inside the goaf-side roadway retained behind the workface (Fig.8). Each drainage pipe has a mixed extraction volume of 100m^3/min and diameter of drainage pipe is 325mm.

As shown in Fig.8, to verify the rationality of drainage pipes layout, 6 measuring points, named as 1#~6#, was arranged behind the hydraulic support to determine gas concentration on the upper corner. The distance between the measuring points is 1.5m and the distance from the height of the floor is 1.5m. Gas concentration was measured several

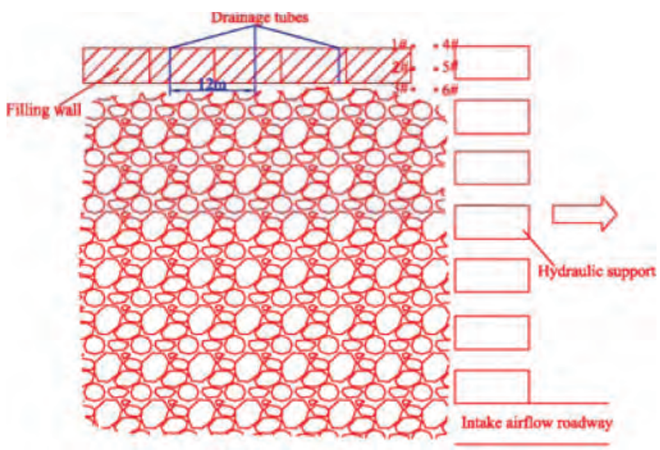


Fig.8 Measuring points layout

times on the upper corner of the workface during the test. The gas concentration behind the hydraulic support was about 0.2~0.5%. There was no gas overrun problem on the upper corner.

5. Conclusion

Based on the engineering practice of Xingwu coal mine in China, reasonable mixed volume for gas drainage and layout of drainage pipes in the goaf to reduce the danger of gas overrun behind the hydraulic supports were studied.

When the mixed volume for gas drainage reaches 300m^3/min, the upper corner gas has obvious movement to the outlet direction and the concentration contour line is backwardly offset in the range of about 30 m near the return airflow roadway, which is favourable for improving the gas treatment condition in the upper corner. Finally, 300m^3/min mixed volume for gas drainage was selected for gas drainage in the goaf.

Taking into account the use of a single drainage pipe required larger diameter, and easy deformation, affecting the gas drainage effect; three drainage pipes instead of a single drainage pipe were arranged at 18m, 30m and 42m inside the goaf-side roadway retained behind the workface.

According to the mining practice, gas concentration behind the hydraulic support was about 0.2~0.5% by the application of the selected mixed volume for gas drainage and drainage pipes arrangement. Gas overrun accidents behind the hydraulic supports were avoided.

Acknowledgments

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