Numerical simulation study on optimization of ventilation airflow organization of a raw coal bunker

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Abstract: For the problem of gas accumulation in the product bunker of a company's coal processing plant, three different ventilation schemes are proposed. The first one opens rectangular air inlet louvers on the wall of the product bunker and adds fans on the top for exhaust; the second one sets six ventilation windows evenly on the top of the product bunker for natural ventilation; the third one sends air to the interior of the bunker through small holes evenly distributed on the ventilation pipes and opens six exhaust ports on the wall. Finally, the effect of gas accumulation management of the ventilation scheme is simulated and analyzed through numerical simulation. The ventilation scheme is applicable to the gas accumulation management of raw coal bunkers with different coal storage heights, and provides a technical reference for the gas accumulation management of product bunkers in coal processing plants.

1 Introduction

After the mined underground coal is transported by belt conveyor into the raw coal bunker, it will block the lower entrance of the bunker tightly, resulting in the gas can be released from the coal pile for a long time and evenly [1]. The raw coal and coal sludge piled up in the raw coal bunker of thermal power plants are not selected and washed, and the gas content is high, so the ventilation requirements are high. The gathering of gas in the coal bunker easily leads to the occurrence of gas disaster accidents, which threatens the personal safety of coal mine production personnel and the safe production of coal processing plants seriously, and practical and effective measures must be taken to eliminate the phenomenon of gas accumulation in the coal bunker. For the problem of gas accumulation in the raw coal bunker of a coal processing plant, domestic coal mining enterprises have taken various technical measures [2, 3], which have solved the problem of gas accumulation to some extent, but the local gas concentration is still high due to the presence of the structures on top of the bunker.

Ma Heng, Guo Yao [4] studied the distribution of gas in coal bunkers and the inlet air speed in winter and summer through numerical simulation and field measurement, the results showed that the gas concentration was distributed in a gradient, gradually increasing from top to bottom and the outdoor temperature was different, the inlet air speed should be adjusted accordingly; Guo Yadi et al [5] studied the gas management scheme of mixed ventilation in coal bunkers by applying FLUENT simulation software, the results showed that for the area with large amount of gas gushing, the mixed ventilation method of press-in and extraction and the method of wind discharge of gas can effectively solve the problem of gas accumulation.

The above-mentioned literature has studied various ventilation airflow organization of coal bunkers and the corresponding gas removal effect, but there are few studies that consider the influence of the beams at the top of coal bunkers and the height of coal piles on gas emission. Since the density of gas is smaller than air, the released gas will gather in the recesses between the beams, and the surface of the coal pile is not flat, so the accumulation of gas is also likely to occur at the highest part of the gas release surface. In this paper, we take the product bunker of a coal processing plant as an example, model the space above the selected gas release surface in 1:1 equal scale, and adopt Computational Fluid Dynamics (CFD) method to simulate and compare the gas concentration distribution and air flow field distribution in the raw coal bunker under different ventilation schemes, especially the gas removal from the recess between the beams. The gas concentration distribution and air flow field distribution in the raw coal bunker under different ventilation schemes were

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simulated and compared, especially the removal of gas from the recesses between the beams.

2 Ventilation solutions

According to the traditional ventilation scheme, the air is generally supplied to the bunker by installing local fans. Although the gas concentration in the bunker can be reduced to different degrees at various points, the local gas concentration in the bunker is still high and the phenomenon of gas accumulation in the bunker has not yet been fundamentally eliminated. Therefore, in this paper, three different ventilation schemes are designed, and the optimal scheme is selected by comparing the velocity field, concentration field and discharge efficiency in the bunker under the same ventilation volume.

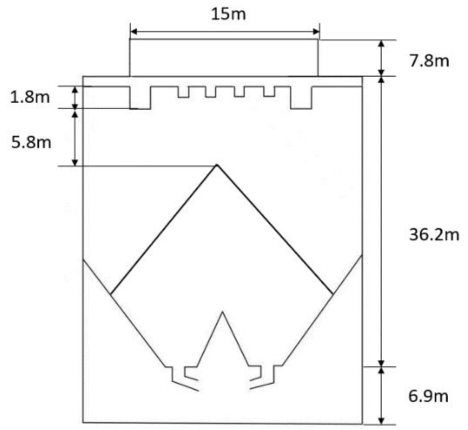

Fig 1. Schematic diagram of coal bunker geometry

The required ventilation quantity Q for diluting explosive or toxic gases in industrial settings is calculated as follows [6,7,8,9,10,11]:

$$Q = \frac{K_x L_d}{C - C_j} \quad (1)$$

Where: Q for dilution of explosive toxic gas ventilation, kg/s or m^3/s; K_x for the consideration of explosive toxic gas distribution of unevenness, distribution and ventilation airflow organization and other factors such as the safety factor, for general ventilation space to take $K_x = 3 \sim 10$, air supply system its air volume calculation to take $K_x = 6$; L_d for the production process unit time gas release, m^3/min; C for the gas volume fraction 0.5% for the alarm value point, that is, C value to take 0.5%. C is the safe allowable concentration of gas, %, existing coal mining enterprises generally choose the gas volume fraction 0.5% as the alarm value point, that is, C value to take 0.5%, when the volume fraction of gas reaches 0.5% gas accumulation is considered to exceed the alarm limit; C_j is the concentration of gas in the inlet air, take 0.

L_d is calculated as follows:

$$L_d = \frac{\rho Q_0}{60 V_c} \quad (2)$$

Where: Q_0 is the average amount of gas gushing out inside the original coal bunker, for the study of gas diffusion law in the original coal bunker, take Q_0 as 1.7 m^3/min; ρ is the density of gas in the coal bunker, set as 0.7 kg/m^3; V_c is the volume of gas release source, set the total volume below the gas release surface as 5674 m^3.

Calculation can be obtained from the amount of gas desorbed from the coal body L_d=4.62×10^{-6}kg/s.

Substituting each parameter into equation (1), the air supply volume Q = 0.0055m^3/s under the mechanical air supply mode of the three ventilation schemes is calculated.

3 Numerical model

3.1 Geometric model and mesh

Considering that the part below the coal pile does not affect the airflow inside the bunker, only the part above the coal pile surface is considered in the modeling. To simplify the model, the gas release surface was simplified to the coal pile surface, i.e., a cone surface with the diameter of the coal bunker as the diameter of the bottom surface, and a 1:1 geometric model was modeled 5.8 m below the top of the bunker.

The model of option 1 is simplified to a total of six beams and one main beam. Two exhaust openings are symmetrically opened in the middle of the second and third beams at the top of the silo to install exhaust fans. Six rectangular air inlets are uniformly opened at the top of the coal pile.

In Scheme 1, the coal bunker is meshed and the boundary layer is encrypted at the junction position between the vent and the bunker wall, and the entire computational model adopts a tetrahedral unstructured mesh with good adaptability, and the total number of meshes is about 180,000.

In the selected area, the air inlet louvers in Option 1 are 0.3×0.3m in size and 3.776m in height, and the exhaust air outlet is simplified to a circular hole of 0.71m in diameter.

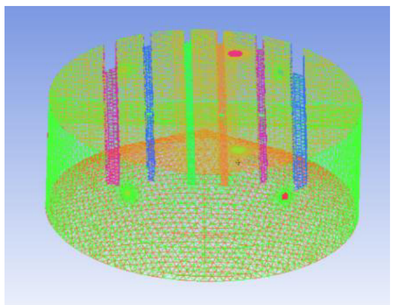

Fig 2. Schematic diagram of scheme I grid division

The model of Option 2 is simplified to open six rectangular air openings uniformly on the top of the silo body to be set as air inlet and outlet respectively. The size of the vent in Option 2 is 0.3×0.3m and the height is 5.626m.

Option 2 uses the same method to mesh the coal bunker, and the total number of unstructured meshes for this option is about 530,000.

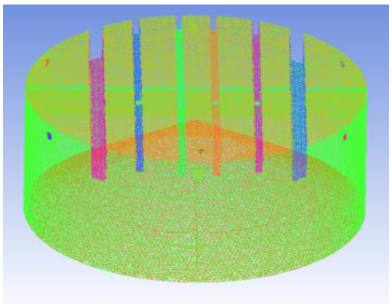

Fig 3. Schematic diagram of scheme II grid division

In Option 3, there are 12 small air supply holes with a diameter of 0.29m, evenly arranged on a square pipe with a side length of 1.78m, and the square pipe crosses the coal buker.

Option 3 is also meshed in the same way, and the entire computational model is meshed with an unstructured grid, with a total number of about 550,000 meshes.

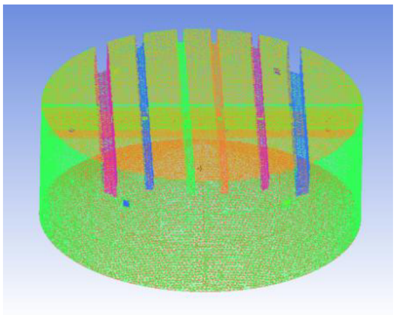

Fig 4. Schematic diagram of scheme III grid division

4 Results and discussion

4.1 Concentration field

Comparative analysis of the concentration fields of the three scenarios:

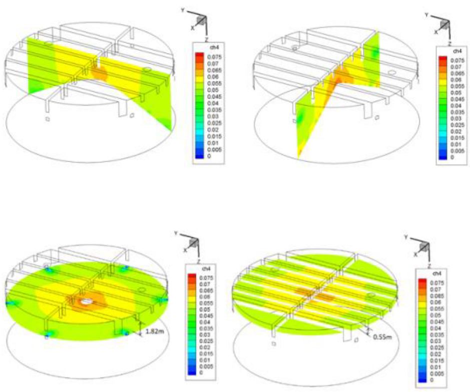

Fig 5. Scheme I concentration field cloud map

It can be seen from the methane concentration field cloud diagram of Option 1 that the methane concentration is obviously reduced at the opened air inlet and air exhaust, but the beam has a certain effect on the methane discharge, and because the coal pile is not a flat surface, the most methane accumulates at the high part of the coal pile. Therefore, it can be seen that the added air inlet and exhaust devices have an obvious effect on methane concentration dilution, and the methane concentration in the rest of the space is effectively controlled except around the silo wall and the release surface.

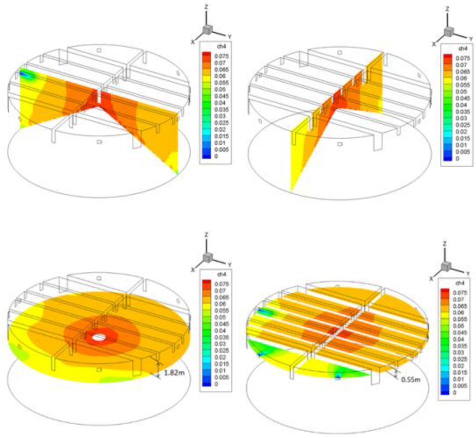

Fig 6. Scheme II concentration field cloud map

From the methane concentration cloud chart of Option 2, it can be seen that the methane concentration at the air inlet decreases obviously, and the air outlet is set on the symmetrical surface of the air inlet, which is intended to facilitate the exhaust, but due to the natural ventilation method and the blocking effect of the beam, the methane is not eliminated in time, thus causing a certain degree of methane accumulation, and the disadvantage is obvious compared with Option 1. However, the disturbance of methane in the coal bunker is more obvious. The problem of high gas concentration between the beams can be improved by adding mechanical air exhaust method.

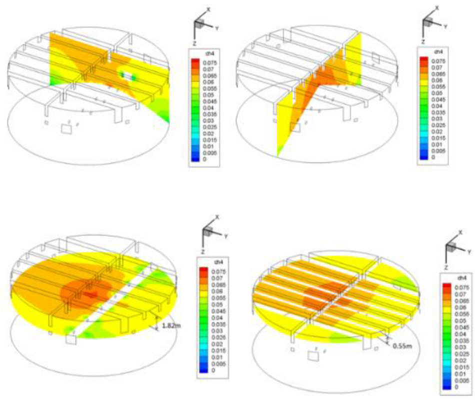

Fig 7. Scheme III concentration field cloud map

From the methane concentration cloud map of Option 3, we can know that the methane concentration on one side of the coal bin with ventilation pipe is obviously much lower than the other side, and the concentration trend has an overall concentric circle distribution, which is related to the shape of the coal pile. However, even under the action of the mechanical air inlet pipe, the methane between the beams still cannot be well discharged from the set air vent, so if this option is adopted, the size and direction of the air inlet need to be considered to prevent the coal dust from blocking the air inlet, and the location of the air vent also needs to be accurately calculated to achieve the maximum dust removal efficiency.

4.2 Ventilation efficiency

The equation defining the overall relative effluent efficiency of the room is:

$$\overline{\varepsilon} = \frac{C_e - C_s}{\overline{C} - C_s} \quad (3)$$

Where: is the mass concentration of pollutants at the exhaust air outlet, kg/m^3; is the mass concentration of pollutants at the air supply outlet, kg/m^3; is the average mass concentration of pollutants in the room, kg/m^3.

The calculation shows that the relative discharge efficiency of Option 1 is 1.017, Option 2 is 1.016, and Option 3 is 0.993, and the comparison of discharge efficiency is shown in Figure 8.

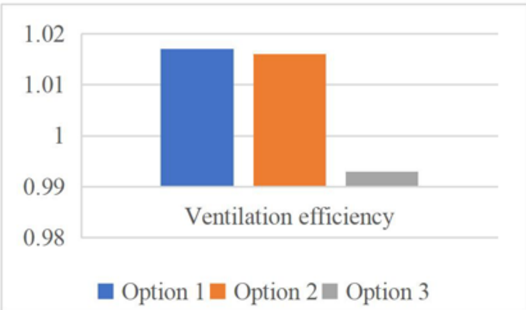

Fig 8.Comparison of the discharge efficiency of the three schemes

It can be seen that, among the three options, the ventilation option of adopting mechanical ventilation at the top of the coal bunker is more conducive to the discharge of methane.

5 Conclusion

In this paper, three different ventilation schemes are proposed for the problem of gas accumulation in the product bunker of a coal processing plant, and the effect of gas accumulation management of ventilation schemes is simulated and analyzed through numerical simulation.

(1) The mechanical ventilation scheme is more flexible, can be adjusted at any time, and is not greatly affected by the internal structure of the coal bin, and can discharge the accumulated gas in time.

(2) The solution of using natural exhaust is more obvious to disturb the gas in the coal bunker, and the discharge efficiency is more prominent, but it is greatly affected by the internal structure of the coal bunker, so it needs specific analysis of the specific coal bunker structure and design of reasonable inlet and outlet positions.

The ventilation scheme proposed in this paper is applicable to the management of gas accumulation in raw coal bunkers of different coal storage heights, and provides a technical reference for the management of gas accumulation in product bunkers of coal processing plants.

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