Research on Dust Source Traceability Based on Dust Migration Law in Working Area of Large Mining Height Fully-mechanized Face

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Abstract: The dust control basis of fully mechanized mining face is clear dust source characteristics. In view of the problem of unclear dust source and unknown distribution characteristics in the working area of 7.8 m large fully mechanized mining face, the fully mechanized mining face of Shendong Bulianta Coal Mine is selected as the The research object adopts the method of combining numerical simulation and field measurement to study the dust migration law based on the single action and joint action of the two main dust sources of shearer cutting coal and column moving frame, and obtains the dust migration law. According to the characteristics, the distribution of respirable dust concentration in the breathing zone of personnel in the vicinity of the shearer was further analyzed. The results show that the dust produced by dropping the column and moving the frame has the greatest impact on the dust concentration in the operator's area. The maximum value of the respirable dust concentration in the operator's area when cutting coal downwind and upwind is in the middle of the shearer, and originates from the shearer cutting coal. The proportions of dust source and column-moving dust source were 44.50% and 76.69%, respectively. The dust traceability research can provide a theoretical basis for the targeted management of dust in fully mechanized mining face with large mining height.

Keywords: large mining height; fully mechanized mining face; dust; migration law.

1. Introduction

In recent years,the state of coal mine safety production has improved significantly in my country,the million-ton death rate fell down from 5.77 in 2000 to 0.044 in 2021[1]. However, the rising trend of occupational hazards of coal mine pneumoconiosis has not been effectively curbed, the number of pneumoconiosis induced is increasing year by year, from 9173 in 2005 increases to 14357 in 2020[2]. At the same time, high concentrations of dust have caused dust explosion accident, difficulties in video surveillance and data collection, resulted in weak signals and extremely poor images. affected the reliability and stability of monitor, transmission and control of automated systems [3~5].Therefore, the hazards of coal dust in fully mechanized coal mining face is not only manifested in inducing pneumoconiosis, but also reducing the degree of visualization of fully mechanized mining.

At present, the large mining height fully mechanized mining technology[6~7] is an inevitable trend to realize the intensive, efficient and safe development of coal production. It has been widely implemented in our country's Shaanbei area and other large coal producetion bases, especially the application of the 7 m and more large mining height fully mechanized coal mining face. In order to improve the mechanization degree and mining intensity of the fully mechanized mining face, the improvement of production efficiency also makes the dust problem of the fully mechanized face increasingly prominent, which urgently needs to be effectively controlled. There is no dust control experience to be followed worldwide, it has only appeared in these few years, with little basic theoretical research [8~12], no corresponding theoretical and technical support, and dust control lacking pertinence[13~16]. This paper is aimed at this problem, and traces the source of dust in the working area of a fully mechanized face with a large mining height of 7.8 m, which can provide a basic theoretical basis for effective dust control in a fully mechanized mining face.

2. Characteristics of dust diffusion

Take a large mining height fully mechanized face of Shendong Company's Bulianta Coal Mine as an example, the maximum mining height of the working face is 7.8 m, which adopts inclined long wall retreat type one-time full height mining, all caving method to deal with the goaf comprehensive mechanized coal mining method, the operation method of end oblique cutting feed, coal cutting,

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rack shifting, pushing scraper conveyor, and the front drum cuts the top coal, the rear drum cuts the bottom coal, bidirectionally cuts the coal, and the round trip cuts 2 knives at a time.The chasing machine moves the frame to support the roof in time, lags behind the shearer front drum by 2 to 3 frames.In addition, the personnel of the large mining height fully mechanized face mostly work on the inside of the hydraulic support column.

Compared with the general fully mechanized face, the large mining height fully mechanized face has unique technology and dust production characteristics followed TABLEⅠ.

TABLE I. MAIN DIFFERENCES BETWEEN TWO FULLY MECHANIZED FACE

Number	items	large mining height fully mechanized face	general fully mechanized face
1	Mining high	≥7 m	5~6 m
2	Coal cutting method	Shearer drums cut coal at a time	One shearer drum cuts the top,the other cuts the down
3	Pedestrian area	Inside of the hydraulic support column	Outside of the hydraulic support column

There are two main sources of dust, coal cutting and column drop, but the dust diffusion path is quite different. Part of the dust in the working area of a large-mining fully-mechanized coal face is diffused from the shield beam when the column is moved down, and part of the dust generated by the shearer cutting coal through the support column. But part of the dust in the working area of the general fully mechanized mining face is the dust generated by the shearer cutting coal, and the part is the dust generated by the falling column moving frame and spreading through the support column. The difference in dust diffusion paths directly affects the proportion of dust sources in the operation area, which in turn determines the difficulty and key points of the management of fully mechanized coal mining faces. The column is moved, and the dust in the working area of the general fully mechanized coal mining face is from multiple sources. The shearer cuts coal, but it is not known how much. Therefore, the study of dust traceability in the working area of a fully mechanized coal mining face with a large mining height of 7.8 m is extremely important for the targeted management of dust.

3. Dust Migration Law

3.1 Numerical Simulation

3.1.1 Simplified physical model establishment and parameters

Establish a simplified physical model based on the large mining height fully mechanized mining face of Bulianta Coal Mine, set the position of the shearer drum and the lowering column moving frame shield beam as the dust source, as shown in Fig. 1, and set the inlet boundary conditions as 1.2 m/s, the standard k-ε two-equation turbulence model and the DPM discrete phase model are selected for calculation which shown in TABLEⅡ.

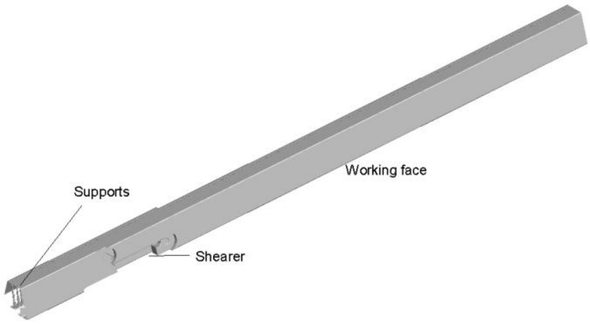


Fig. 1. Simplified physical model

TABLE II. MODEL PARAMETERS & DPM MODEL PARAMETER SETTING TABLE

Number	Parameters	Value
1	Stope space	150 m long, 9 m wide, 7.8 m high
2	Shearer body	10m×3.6m×3.6m
3	Shearer drum	diameter 4.5 m,cut-off depth 0.865 m
4	Coal baffle	140 m long, 200 mm thick, 3m high,
5	Length of frame moving area	115 m upwind, 35 m downwind
6	Length of unmoved frame area	35 m upwind, 115 m downwind
7	Coal cutting method	downwind/upwind
8	Injection type	Surface
9	Release from surfaces	Injet
10	Material	Coal-lv
11	Diameter distribution	Rosin-rammler
12	Min.diameter	1e-6 μm
13	Max.diameter	1.0e-5
14	Mean diameter	5.5e-6 μm
15	Spread parameter	1.2 m
16	Total flow rat	0.015 $kg{\cdot}s^{-1}$
17	Turbulent dispersion	Stochastic tracking
18	Number of tries	20
19	Time scale constant	0.15

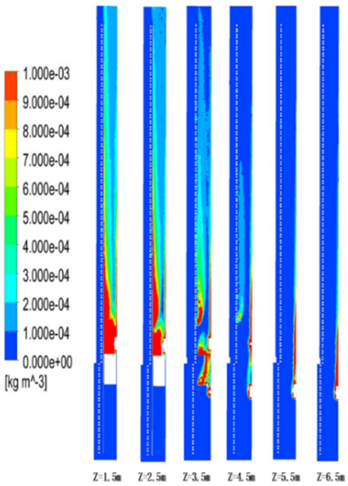
3.1.2 Respiratory dust distribution in the working area

There are two main dust sources,coal shearer cutting coal and lowering column moving frame. In order to be able to analyze these two dust sources in depth, a single dust source and a double dust source were simulated respectively.According to the difference between the direction of the wind flow and the direction of the shearer, the shearer can be divided into downwind coal cutting and upwind coal cutting.When the shearer cuts the coal downwind, the downwind drum cuts the top coal and the upwind drum cuts the bottom coal. When the shearer cuts the coal upwind, the upwind drum cuts the top coal and the downwind drum cuts the bottom coal. The working conditions are quite different.

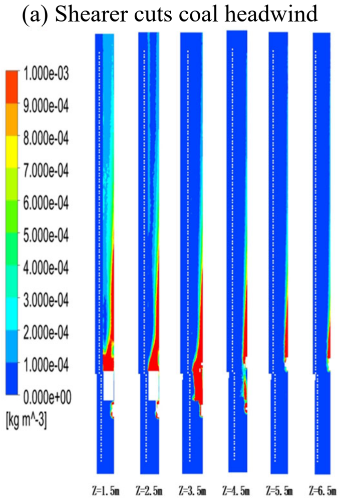
Based on the above calculation model and parameter settings, calculate the dust concentration distribution when the two main dust sources of coal shearer cutting coal and lowering column moving frame act independently at first.

Single dust source

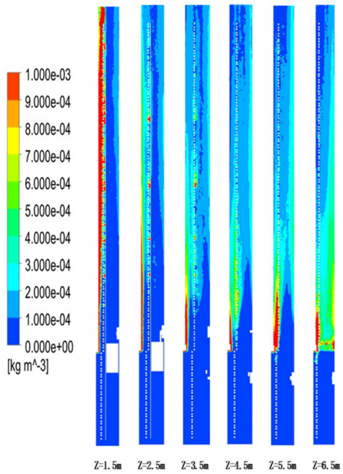
When a single dust source acts, it needs to be calculated separately. The dust source of the descending column moving frame is generally located in the middle of the shearer, and the diffusion is basically the same when the downwind and the headwind. The dust concentration distribution on the cross section parallel to the direction of the bottom of the working face is shown in Fig. 2 below. The dust concentration in the breathing zone of the personnel working area near the shearer (Y=10-50m, X=2.6 m, Z=2.85 m straight line in the model) The distribution is shown in Fig. 3 below.



(a) Shearer cuts coal headwind



(b) Shearer cuts coal downwind



(c) Descending pillar and moving frame

Fig. 2. Distribution of dust concentration in fully mechanized mining under the action of a single dust source

It can be seen from Fig. 2 that in the two working conditions of cutting coal with downwind and cutting coal with upwind, most of the dust produced by the coal cutting drum of the shearer moves downwards in front of the column with the wind, and then a small part gradually moves to the sidewalk. Diffusion on one side; most of the dust generated by the lowering column moving frame moves downward along the top beam of the support and the inner wall of the shield beam with the wind, and the range of diffusion influence is much larger than the influence range of coal cutting by the shearer drum. In addition, the dust concentration in the working area near the shearer is much lower than the airflow area under the shearer in the three working conditions. It can be seen from Fig. 3 that the high dust concentration of the breathing zone near the shearer is below 400 mg/m³, and the dust generated by the single dust source of coal cutting by the upwind shearer gradually diffuses to the sidewalk from the position of Y=25 m. And the diffusion rate is slow; the dust produced by the single dust source of the downwind coal shearer is gradually diffused from the position of Y=30 m to the sidewalk, and the diffusion rate is relatively fast, reaching about 130 mg/m³ at the position of Y=40 m; and The dust generated by the single dust source of the descending column moving frame reaches the highest value at the position of Y=35 m, about 90 mg/m³, and then there is a trend of first falling and then rising.

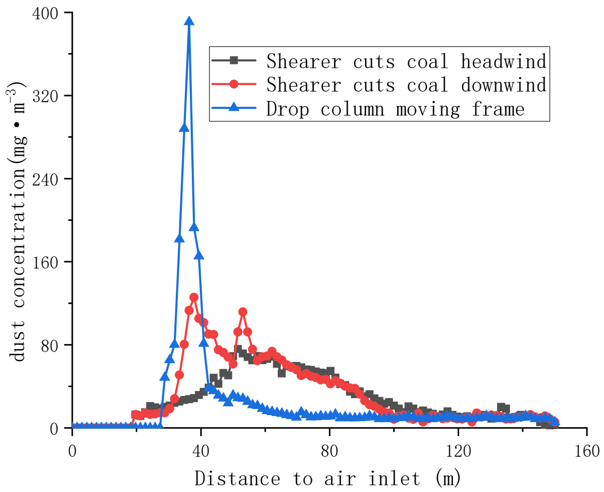
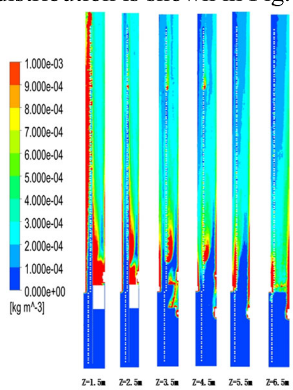


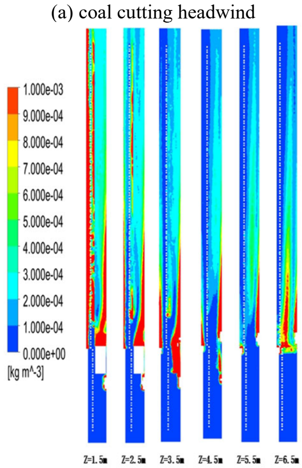
Fig. 3. Distribution of high dust concentration in the breathing zone near the coal shearer when a single dust source is applied

Double Dust Source

The dust concentration distribution is calculated when the two main dust sources of coal shearer cutting coal and falling column moving frame work together on the basis of the single source calculation. The dust concentration distribution on the cross section parallel to the direction of the working face floor under the two working conditions of upwind and downwind coal cutting is obtained as shown in Fig. 4 below. The breathing zone of the personnel working area near the shearer (Y=10-50m, X=2.6 m, Z=2.85 m straight line in the model) .The dust concentration distribution is shown in Fig. 5 below.



(a) coal cutting headwind



(b) coal cutting downwind

Fig. 4. Dust concentration distribution diagram when two dust sources work together

Fig. 4 shows that in the two working conditions of headwind and downwind coal cutting, the dust produced by the coal shearer drum moves down along the side of the coal wall with the wind flow, and the dust produced by the lowering column moving frame moves along the side of the support with the wind flow. It moves down and merges at Y=70m, and then diffuses in the entire sidewalk operation area. The combined impact of the dust generated by the two dust sources of coal cutting in headwind is significantly greater than that of coal cutting in downwind.

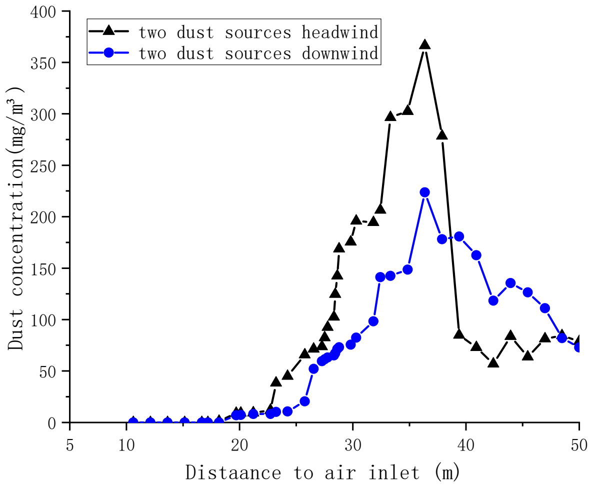


Fig. 5. .Distribution of high dust concentration in the breathing zone near the coal shearer when the two dust sources work together

Fig. 5 shows that when the two dust sources work together, the dust concentration in the working area of the personnel near the shearer starts to increase from Y=23m under the two working conditions of downwind coal cutting and upwind coal cutting. The position of Y=36 m reaches the highest value, and the maximum concentration of respirable dust under the two working conditions of headwind and downwind coal cutting is about 360 mg/m³ and 225 mg/m³ respectively.

3.2 Field test

In order to further grasp the law of dust migration in a fully mechanized mining face with a large mining height of 7.8 m, the concentration of respirable dust on the walkside of the fully mechanized mining face in Bulianta Coal Mine was tested on-site. The measurement points are arranged as shown in Fig. 6.Dust concentration measurement points are arranged at the pedestrian side of the hydraulic support, and one measurement point is arranged at an interval of 2.05 m from the air inlet to the air outlet.

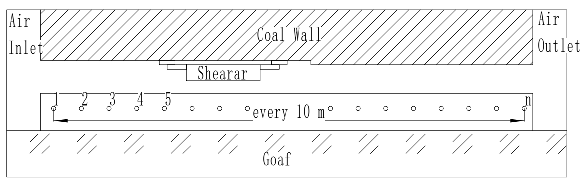
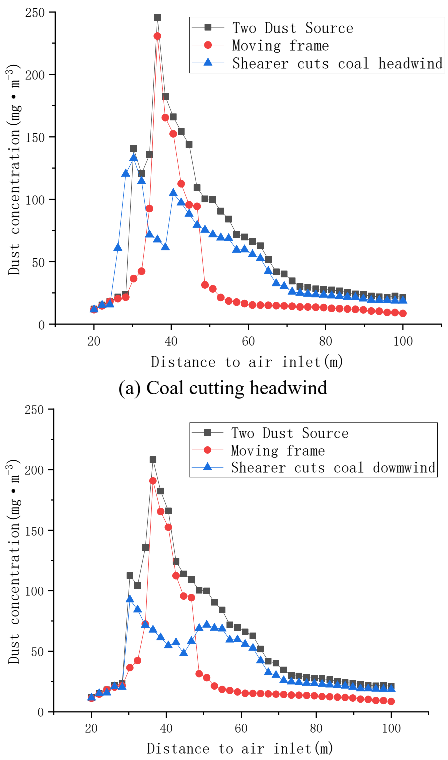


Fig. 6. Layout of dust concentration measurement points

In order to obtain more accurate test data, first arrange the shearer to suspend the coal cutting operation, only carry out the operation of lowering the column and moving the frame, and arrange for multiple people to perform dust measurement at the same time to obtain the breathability at the height of the breathing zone of the personnel working area when the column is being moved down. Dust concentration, and then arrange to suspend the lowering of the column and moving the frame, arrange for multiple people to perform dust measurement at the same time to obtain the respiratory dust concentration at the height of the breathing zone of the personnel working area under the conditions of downwind and headwind. The test results are shown in Fig. 7 below.



(a) Coal cutting headwind

(b) Coal cutting downwind

Fig. 7. Respirable dust concentration at the height of the breathing belt in the personnel work area

As shown in Fig. 7, when a single dust source is applied to the hydraulic support, the dust concentration in the breathing zone of personnel at a position 5 m downwind from the dust source point (the middle of the shearer, at the abscissa 35m in the figure) The maximum can reach 230.7 mg/m³, but after a period of settlement, it will be reduced to 20 mg/m³ at the 40 m downwind side of the dust source (at the abscissa 75m in the figure), and finally enter the return air lane. When cutting coal in a downwind, when the coal dust source of the shearer cuts alone, the highest dust concentration that diffuses to the sidewalk space is 245.2 mg/m³. At the position of 10 m from the tail of the machine, the coal shearer cuts coal and the column moves two dusts. The highest concentration of sidewalk respirable dust is 203.8 mg/m³ when the sources are combined, which is located in the middle of the coal machine. When cutting coal against the wind, when the coal dust source of the shearer cuts alone, the highest dust concentration that diffuses to the sidewalk space is 104.7 mg/m³. At the central position of the shearer, the highest dust concentration of the sidewalk when the two dust sources work together is 165.9 mg/m³, still in the middle of the shearer.

4. Analysis of the proportion of dust sources in personnel working areas

Combining the numerical simulation and field measurement results, it can be seen that the dust concentration of the shearer when cutting coal upwind is greater than that when cutting coal downwind, and the dust concentration of dust produced by dropping the column and moving the frame is greater than that of the shearer cutting coal. The comparison between single dust source and double dust source shows that the dust concentration of double dust source is not the sum of the dust concentration of single dust source, but is more affected by the maximum value of dust concentration of single dust source. Analysis as follows.

In order to further verify the on-site measured data, the dust concentration at the height of the breathing zone of the personnel working area near the shearer under the combined action of the coal cutting of the shearer and the lowering of the pillar moving frame was compared, Comparison of dust concentration between numerical simulation and field measurement

To sum up, it can be seen that the results of the numerical simulation and the actual measurement of the respirable dust concentration in the working area near the shearer are basically the same, which can well reflect the dust pollution near the shearer in a fully mechanized coal mining face with a large mining height of 7.8 m. It can be seen that when the shearer cuts coal downwind, the highest point of respirable dust in the sidewalk area is located in the middle of the shearer, which is 208.3 mg/m³. The ratio is about 44.50%; when the shearer is cutting coal against the wind, the highest point of respirable dust in the sidewalk area is also located in the middle of the shearer, which is 118.3 mg/m³. The ratio is about 76.69%.

5. Conclusion

(1) Through numerical simulation and field measurement, the dust migration rule is obtained: the dust concentration of coal cutting by shearer is obviously less than that of hydraulic support, and the dust produced by coal cutting by shearer is greater than that by downwind.

(2) Through the results of numerical simulation and on-site measurement, it can be seen that in the two working conditions of downwind and upwind coal cutting in a fully mechanized coal mining face with a large mining height of 7.8 m, most of the dust generated by the coal cutting of the shearer drum is in front of the support moving. The wind flow moves downwards, and then a small part gradually spreads to the sidewalk side; the dust produced by the lowering column moving frame mostly moves downwards along the sidewalk side with the wind current, and the air current merges under the shearer, and the falling column moves the frame dust When the source is single-acting, the range of diffusion influence is much larger than that of the coal-shearer cutting coal dust source.

(3) The results of numerical simulation and on-site measurement are almost the same. Under the combined action of two dust sources, the highest concentration of sidewalk respirable dust is in the coal machine under the two working conditions of downwind coal cutting and upwind coal cutting in a fully mechanized coal mining face with a large mining height of 7.8 m. The central position is 208.3 mg/m³ and 245 mg/m³, where the dust generated by the lowering column moving frame is 230.7mg/m³, accounting for 44.50% and 76.69% respectively, which are significantly different from the general mining height fully mechanized face. Therefore, in the prevention and control of dust in fully mechanized mining face, it is necessary to focus on effective control of the dust source of dropping column and moving frame. This paper digitizes the proportion of dust sources, but lacks in-depth research on dust particle size.

Acknowledgments

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