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Analysis of Factors Affecting Dust Concentration Detection Accuracy Based on the Orthogonal Experiment

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Abstract*:* In order to improve the detection accuracy of the charge-sensing dust concentration detection technology, a charge-sensing dust concentration detection experimental platform was built. Based on the orthogonal experiment, the temperature, humidity, coal type, wind speed and other factors were analyzed to determine the dust concentration of the charge-sensing method. The impact of detection technology detection accuracy. The research results show that the order of influence of the charge-sensing dust concentration sensor detection accuracy from primary to secondary is: coal type, humidity, wind speed, temperature, among which coal type plays a vital role. The research results provide a theoretical reference for the research on the detection accuracy of charge-induced dust concentration, which has important scientific significance.
Keywords Dust; Orthogonal experiment; Charge induction method dust concentration detection; Detection accuracy; Influencing factors

INTRODUCTION

Mine dust is one of the five major disasters in coal mines. Mine dust refers to the general term for fine solid particles such as coal and rock produced by coal mines in the production process [Li, 2000]. It is mainly produced in the production and transportation of coal, drilling and shooting, coal burning, moving columns, coal. In the reloading, dust with different sizes of coal particles is formed under the action of wind. The biggest hazard of dust is serious threat to the health of the miners. [Xu, 2018] Especially the dust with a particle size of less than 5μm is inhaled into the lungs for a long time, which is easy to get pneumoconiosis. The medical level, pneumoconiosis is still an incurable disease that can only be prevented and not curable [Lu et al., 2008 and Zhang et al., 2008].

According to Zhang Mingqi, vice chairman of the National Federation of Trade Unions, a total of 24,209 occupational diseases were reported nationwide in 2017, of which 12,405 and 10,594 were coal pneumoconiosis and silicosis, respectively, and the number of reported cases of pneumoconiosis accounted for 88.28% of the total number of occupational disease reports in 2017. Zhang Baoming, chairman of the China Occupational Safety and Health Association, said that according to preliminary estimates, the current annual incidence of pneumoconiosis deaths in the industry has exceeded twice the death toll from production safety accidents. [L. Hao, *et. al.*, 2018]

Pneumoconiosis not only threatens the lives and health of patients, but also causes huge losses to the national economy. According to incomplete statistics, the direct economic losses caused by pneumoconiosis can reach 8 billion yuan each year, and its indirect losses are immeasurable, resulting in very bad social impact. Therefore, it is necessary to conduct real-time online accurate detection of dust concentration in coal mines.

The traditional method for realizing dust concentration on-line detection technology mainly includes light scattering method, but this technology has problems of optical window pollution and pipeline blockage [Huang et al., 2011]. Therefore, scholars at home and abroad are studying a new online detection technology for dust concentration. - Charge induction method dust concentration detection technology [Chen et al., 2015, Rani et al., 2015, Zhao et al., 2010]. This technology is still immature, and all scholars are in the experimental exploration stage. Therefore, this paper focuses on the influence of external factors on the accuracy of charge induction dust concentration detection. Attempts to study the main factors affecting the accuracy of the charge-sensing dust concentration detection through experimental data acquisition and analysis, and to indicate the direction for improving the detection accuracy of this technology.

EXPERIMENTAL SYSTEM CONSTRUCTION

The charge induction method dust concentration detection experimental system mainly consists of air compressor, quantitative dust collector, pneumatic pick, electrostatic precipitator, fan, wind speed measuring instrument and computer control platform. The schematic diagram of the experimental system is

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shown in Figure 1. The working principle of the experimental system is that the air compressor sends the compressed air to the quantitative dust collector, and the dust sprayer sprays the dust to the wind, and at the same time, the air is sucked into the wind by the action of the fan, and the wind is formed in the wind. Gas-solid two-phase flow, in order to prevent dust from polluting the air, the electrostatic precipitator is used to remove dust, and finally the purified air is discharged into the atmosphere. [R. Wang, *et. al.*, 2018] The frequency of the fan is adjusted by the computer platform to change the wind speed in the wind, and the dust of the dust collector is changed. The mouth adjusts the dust concentration in the wind. Install a humidifier and a temperature regulator at the air inlet to adjust the humidity and temperature of the air in the wind. The wind speed can be adjusted by adjusting the fan speed. Different concentrations and types of coal powder are transported to the wind through the dust collector. The gas sample is collected, and the weight gain value of the filter is Δm by the balance weighing. The volume of the gas collected by the sampler is V, and the actual dust concentration in the wind is $C=\Delta m/V$, and C is used as a measure of the dust concentration of the charge induction method. The reference value of the sensor detection accuracy.

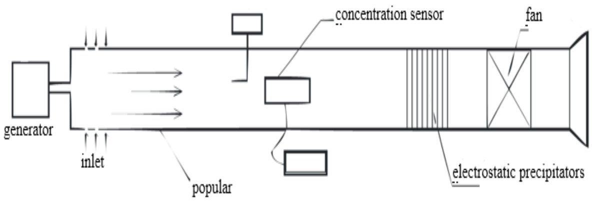

Figure 1. The status of technology management

The external factors mainly study the four factors of temperature, humidity, wind speed and coal type. The temperature is 10~30 degrees according to the normal temperature range. It is divided into three levels of 10 degrees, 20 degrees and 30 degrees. The humidity is selected according to the working conditions of the coal mine which divided into three levels of 60%, 80%, 100%. The wind speed is 1.5m/s~3.5m/s according to the situation of coal mine underground, divided into three levels of 1.5m/s, 2.5m/s, 3.5m/s. Lignite, bituminous coal, anthracite are selected as the coal types. And the specific levels and factors are divided as shown in Table 1.

Table 1. Test level factors

Level	Factor			
	A	B	C	D
	Humidity (%)	Temperature (℃)	Wind speed (m/s)	Coal type
1	60	10	1.5	lignite
2	80	20	2.5	bituminous
3	100	30	3.5	anthracite

According to the experimental scheme, the experiment of 4 factors and 3 levels was determined. If the whole experiment requires 43 experiments, the number of experiments is too many to be completed in a short time. Therefore, the orthogonal test method is adopted, and the orthogonal test method is arranged by orthogonal table. And a design method for analyzing multi-factor experiments [Dong et al., 2004, Yu et al., 2010]. From the total level combination of test factors, select some representative level combinations for testing, and analyze the results of this part of the test to understand the overall test situation and find the optimal level combination. The typical feature is that part of the test is used instead of the comprehensive test, and the analysis of some test results is used to understand the situation of the comprehensive test.

This experiment is a 4-factor 3-level experiment. The factors are independent of each other. Therefore, the L9 (34) orthogonal experimental table is selected as shown in Table 2. The experimental index is the detection accuracy of the charge-sensing dust concentration detection value δ. Calculated as follows

$$\delta=|c1-c2|/c\times 100\% \quad (1)$$

where, C1 is a dust concentration value detected by a charge induction method; C2 is the sampler collects the dust concentration value obtained by weighing.

Table 2. L9 (34) orthogonal experiment

No.	Column number			
	1	2	3	4
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

Design the design of this experiment according to L9 (34), as shown in Table 3.

Table 3. Experimental design scheme

No.	A	B	C	D	Combination
1	A1	B1	C1	D1	A1B1C1D1
2	A1	B2	C2	D2	A1B2C2D2
3	A1	B3	C3	D3	A1B3C3D3
4	A2	B1	C2	D3	A2B1C2D3
5	A2	B2	C3	D1	A2B2C3D1
6	A2	B3	C1	D2	A2B3C1D2
7	A3	B1	C3	D2	A3B1C3D2
8	A3	B2	C1	D3	A3B2C1D3
9	A3	B3	C2	D1	A3B3C2D1

TEST RESULTS AND ANALYSIS

For the analysis of orthogonal test results, two analytical methods are usually used, one is the visual analysis method (or the range analysis method); the other is the variance analysis method.

(1) The visual analysis method

According to the level combination specified in the test number of the test plan of Table 3, one test is to be done 9 times, and the test index (detection error of each sensor) is filled in the last column. The test results and analysis data are shown in Table 4. According to the Table 4, the order of influence of the charge-sensing dust concentration sensor detection accuracy from primary to secondary is: coal type, humidity, wind speed, temperature.

Table 4. Test data and results analysis

No.	A	B	C	D	Error (%)
1	1	1	1	1	5
2	1	2	2	2	3
3	1	3	3	3	9
4	2	1	2	3	15
5	2	2	3	1	7
6	2	3	1	2	9
7	3	1	3	2	3
8	3	2	1	3	18
9	3	3	2	1	5
K1	17	23	32	17	
K2	31	28	23	15	
K3	26	23	19	42	
k1	5.67	7.67	10.67	5.67	
k2	10.33	9.33	7.67	5.00	
k3	8.67	7.67	6.33	14.00	
R	4.67	1.67	4.33	9.00	
Primary and secondary factors	D-A-C-B				

(2) The variance analysis method

In order to further verify the size of each influencing factor, the variance analysis was performed on the orthogonal experimental results.

According to the following formula,

$$T = \sum_{i=1}^{9} y_i = 74$$

$$Q = \sum_{i=1}^{9} y^2{}_i = 828$$

$$P = \frac{T^2}{n} = \frac{74^2}{9} = 608.44$$

Therefore $SS_T = Q - P = 219.56$ .According to this data, the variance analysis table is listed as shown in Table 5.

From the Table 5, the variance analysis table shows that the temperature has no significant effect on the test results. The humidity and wind speed have less influence on the test results, while the coal types have a greater influence on the test results.

Table 5. Analysis of variance

Differences source	SS	df	MS	F
A	33.56	2	16.78	0.611
B	5.56	2	2.78	0.101
C	29.56	2	14.78	0.538
D	150.89	2	75.445	2.74
Error	219.56	8	27.445	

CONCLUSION

(1) The effects of temperature, humidity, wind speed and coal type on the detection accuracy of dust concentration in charge induction method were studied. According to the design of orthogonal test analysis, the coal type has a great influence on the detection accuracy of the sensor, and it is very significant. The influence, humidity and wind speed have a small effect on the detection accuracy of the sensor, with a small significant effect, and the temperature has little effect on the detection accuracy of the sensor.

(2) Through the results of this experiment, we have pointed out the direction for improving the accuracy of charge induction dust concentration detection, which has a high research significance.

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