Dust concentration detection technology of electrostatic induction method

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Keywords: Electrostatic induction method，Dust concentration, High precision, maintenance free

Abstract: In order to solve the shortcomings of the current optical dust concentration sensor commonly used in coal mines, which is easy to block and easily polluted, this paper presented an electrostatic induction method for dust concentration detection technology, according to the electrostatic characteristics of coal mine dust. Firstly, the basic principle of electrostatic induction method was introduced in detail, and then the circuit for signal acquisition and amplification of electrostatic induction signal was designed. Based on the experimental platform built, the signal intensity of electrostatic induction at different concentrations was analyzed, and the mathematical relationship between electrostatic induction signal intensity and dust concentration was obtained. Finally, the electrostatic induction dust concentration sensor was designed. The detection accuracy was verified in the laboratory, and the detection error was less than 10%. It is proved by the underground coal mine experiment that the dust concentration sensor of electrostatic induction has good practicability.

1. Introduction

Dust hazard is one of the five major disasters in coal mines[1]. Dust is the main cause of pneumoconiosis[2]. According to the "Statistical Bulletin on the Development of Health and Wellness in China 2017" released by the National Health and Wellness Committee of the People's Republic of China on June 12, 2018, there are 22,701 new cases of pneumoconiosis in China in 2017. Therefore, in order to improve the health of coal miners, it is necessary to strengthen the supervision of coal mine dust, and it is very important to monitor and monitor the dust concentration in coal mines. At present, most of the coal mines use the laser scattering method dust concentration sensor, but the laser scattering method dust concentration sensor optical window is easy to pollute, and the pipeline is easy to block[3]. The shortcoming make the laser scattering method dust concentration sensor has low detection accuracy and poor practicability. The detection error of the light scattering method dust concentration sensor is 15% [4]. In order to solve this problem, we proposed a dust concentration detection technology based on electrostatic induction according to the electrostatic characteristics of dust.

2. Introduce the principle of electrostatic induction;

Dust has a certain amount of static electricity, due to friction during the production process[5]. When the dust particles with static electricity pass through the detecting electrode, the reverse charge is induced on the surface of the detecting electrode by the principle of electrostatic charge induction. As the dust particles approach the probe electrode, the induced charge on the surface of the probe electrode is gradually increased. As the dust particles move away from the probe electrode, the charge induced on the surface of the probe electrode is reduced. Schematic diagram of electrostatic induction principle is shown in Fig.1. I have verified this principle of induction through experiments[6].

According to Fig.1, the dust particles generate an alternating current signal on the surface of the detecting electrode. The greater the concentration of dust particles, the greater the charge of the dust particles, and the greater the volatility of the generated electrostatic induction signals. The dust particle concentration is positively correlated with the volatility of the alternating signal. Though detecting the volatility of the alternating signal generated by electrostatic induction, dust concentration value is described. It should be noted that the wave signal generated by electrostatic induction is generated by dynamic dust particles rather than deposited dust particles. Therefore, the electrostatic induction dust concentration detection technology is not affected by the deposition dust, so frequent maintenance is not required.

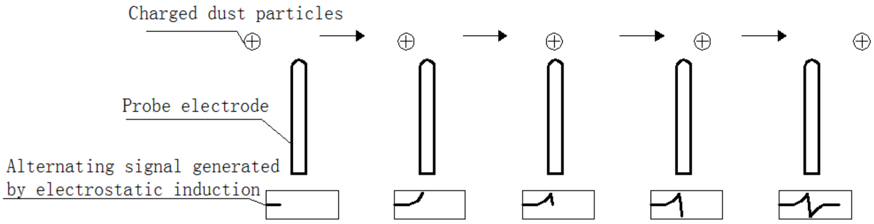


Fig.1 Schematic diagram of charge sensing principle

3. Electrostatic induction signals is Collected

The electrostatic signal induced by the dust particles on the surface of the detecting electrode is captured and amplified by the charge amplifying circuit. The electrostatic induction signal is further amplified by the process control amplifier circuit, and the amplification is controlled by a single chip. Through the designed filter circuit, high-frequency clutter and power frequency interference in electrostatic induction signals are filtered. Finally, the electrostatic induction signal is converted into a digital signal through the designed A/D conversion circuit. Digital signal inputted into the microcontroller is converted into dust concentration value by correlation operation. The flow chart of the signal acquisition circuit of the electrostatic induction method is shown in Fig.2.

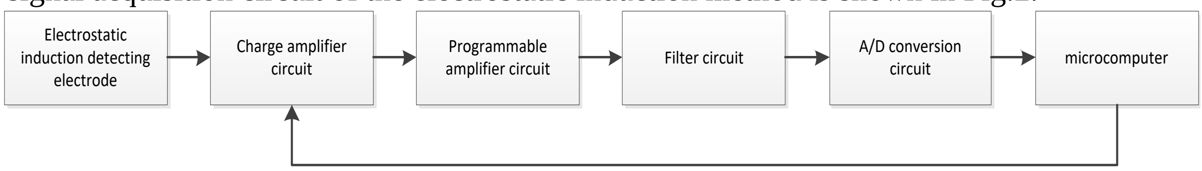


Fig.2 Flow chart of signal acquisition circuit design by electrostatic induction

Because the dust particles have very little static electricity, the electrostatic induction charge signal intensity is extremely low, only a few dozen fA. Static induction signals are easily annihilated by noise during signal processing. So the design of the charge amplifier circuit is more difficult. Charge amplifiers require high input impedance, high common-mode rejection ratio, low noise, low temperature drift, and low input bias. After querying technical data, the charge amplifier circuit uses the amplifier OPA128. Its connection circuit is shown in Fig.3.

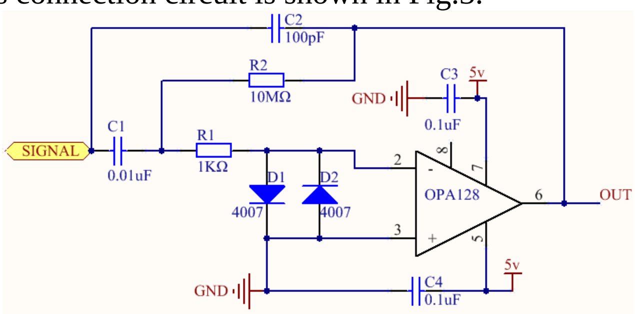


Fig.3 Schematic diagram of the charge amplifier circuit

4. Mathematical model between the volatility of electrostatic induction signals and dust concentration

In order to study the mathematical model between the fluctuation of electrostatic induction signal and dust concentration, firstly a test system with balanced, stable and quantitative adjustment of dust concentration was established. The electrostatic detection electrode is placed in a dusty environment. Electrostatic induction signals were collected under different dust concentration conditions. By analyzing the volatility of the electrostatic induction signal, the mathematical relationship between the volatility of the induced signal and the dust concentration was obtained.

The experimental system of dust was shown in Fig.4. Quantitative dust sender blow dust into the wind. The computer control platform adjusted the wind speed by controlling the inverter fan. In order to distribute the dust evenly in the wind, the wind speed was set at 2 m/s. In order to recover dust, there was a dust collector at the exhaust port of the wind. Aim to obtain the actual dust concentration in the wind, the test system was equipped with a sampler and a balance.

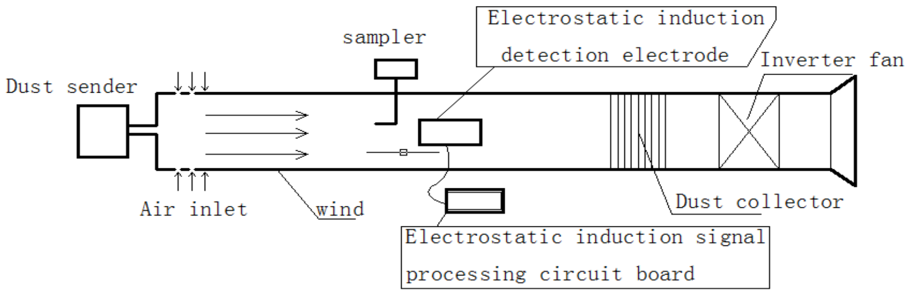
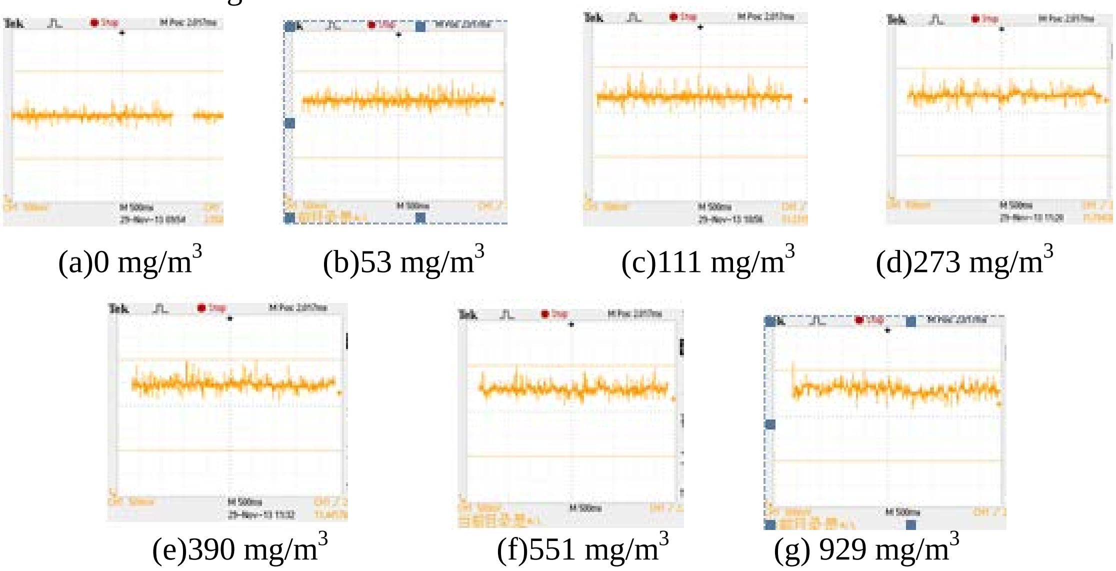


Fig.4 Experimental system of dust

The dust collector continued to work. When the wind speed of the fan was constant, the dust concentration in the wind gradually stabilizes. First we used a balance to weigh a clean filter, and the weight of the filter was M1, and then put the filter into the sampler. The sampler and the electrostatic induction dust concentration detector operated for two minutes at the same time. We recorded the sampler's volume of collected gas as V. The filter was removed from the sampler and the value was weighed M2. Finally, the actual dust concentration value in the wind raft was calculated by the formula (M2-M1)/V. We used an oscilloscope to intercept the induced signal generated by the dust concentration detector. The experimental results were shown in Fig.5. Finally, the standard deviation of the induced signal generated by the dust concentration detector was calculated. The statistical results were shown in Fig.6.



(a)0 mg/m^3 (b)53 mg/m^3 (c)111 mg/m^3 (d)273 mg/m^3

(e)390 mg/m^3 (f)551 mg/m^3 (g) 929 mg/m^3

Fig.5 Collecting electrostatic induction signals

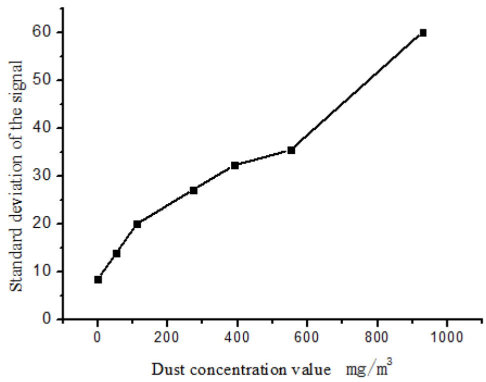


Fig.6 Relationship between dust concentration and standard deviation of electrostatic induction signals

According to Fig.6, the standard deviation value of the electrostatic induction signal increases as the dust concentration increases. The linearity between the standard deviation value of the electrostatic induction signal and the dust concentration was better. The mathematical relationship between the standard deviation value of the electrostatic induction signal and the dust concentration was obtained by the fold line in Fig.6. The electrostatic induction dust concentration detector was calibrated by the fold line in Fig.6. The electrostatic induction dust concentration detection could accurately detect the dust concentration.

5. Experimental verification

The test was carried out in the laboratory using the experimental apparatus shown in FIG. We recorded the sampler test results and the results of the electrostatic induction tester. As shown in Table 1. The detection error of the electrostatic induction dust concentration detector was counted.

Table1 Detection error statistics of electrostatic induction dust concentration detector

Dust concentration g/m^3	Electrostatic dust concentration detector g/m^3	error %	Dust concentration mg/m^3	Electrostatic dust concentration detector mg/m^3	Error %
18	16	-9	236	223	-6
33	35	7	291	304	4
63	58	-8	312	321	3
75	68	-10	362	391	8
96	91	-5	427	445	4
121	112	-7	462	460	0
116	126	9	583	613	5
151	160	6	732	743	1
196	180	-8	894	859	-4

According to the statistical results in Table 1, the detection error of the electrostatic induction detector is less than 10%. Therefore, the electrostatic induction detector has a high detection accuracy.

In order to verify the use of the electrostatic induction dust concentration detector in coal mines, we made a testing in a mine in China Shendong Coal. The data of the detector was transmitted to the ground monitoring center through the coal mine safety monitoring system. The test data for one day was recorded as shown in Fig.7.

We analyze the testing data in the coal mine. When the coal mining machine was not working, the electrostatic induction dust concentration detector had a detection result of about 2 mg/m3. When the shearer was working, the electrostatic induction dust detector had a detection value of about 50 mg/m3. The results of sampling and testing by the sampler in the coal mine were consistent with the results of the electrostatic induction dust concentration detector. Therefore, the electrostatic induction dust concentration detection technology has good usability in the field.

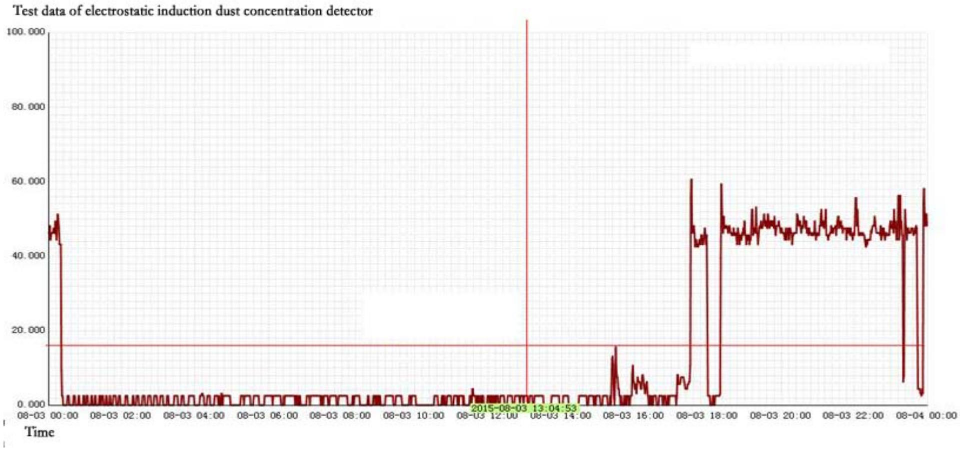


Fig.7 Coal mine test data of electrostatic induction dust concentration detector

6. Conclusion

(1) A capture amplifying circuit with ultra-low charge sensing signal is designed to realize the amplification and extraction of the electrostatic induction signal.

(2) The mathematical model between the standard deviation of the electrostatic induction signal and the dust concentration was determined by the experimental test method.

(3) Through laboratory tests and underground coal mine field tests, it is proved that the electrostatic induction dust concentration sensor has high detection accuracy, and the error is less than 10%. The electrostatic induction dust concentration sensor has strong applicability in coal mines. The electrostatic induction dust concentration sensor is basically maintenance-free.

Acknowledgments

This study was financially supported by National key research and development plan (2016YFC0801700).

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