Calibration and Error Analysis of Mine Dust Monitoring System

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Abstract. Since most of China's coal mines have not taken effective measures to prevent dust and dust, the harm of dust to the human body has been in a high situation. At present, there are still some problems in the reliability and detection accuracy of most dust monitoring systems. In this paper, a large number of simulation experiments have been carried out, and the test data have been used to verify the results. The reliability and measurement accuracy of the dust monitoring system are verified from the calibration and repeatability of the monitoring system. At the same time, the error sources that affect the accuracy of the monitoring system are analyzed and the solutions are proposed. The system is improved in the subsequent experiments, which improves the accuracy and reliability of the system measurement.

1. Introduction
During the coal mining operation, a large amount of dust will be generated in the roadway, which will not only affect the operation of the production, but also cause great harm to the health of the coal mining workers, causing pneumoconiosis. Moreover, when the dust concentration reaches a certain limit and there is open fire, dust explosion accidents will occur, threatening the safety of mine production. Therefore, mine dust concentration monitoring has become an important part of coal mine safety production. It is necessary to timely and effectively monitor the dust generated in the production process, and take effective dust removal and dust reduction measures to ensure the safety of life on the job site.

As one of the main factors affecting the safety production of coal mines and the life and health of workers, dust is monitored online, and corresponding effective dust removal and dust prevention measures are taken. Therefore, research and development of instruments for online monitoring of mine dust concentration are of great significance. It is urgent to develop an instrument for online monitoring of dust concentration suitable for coal mine engineering applications [8]. In recent years, with the continuous development of sensor technology, the online monitoring technology of dust concentration has developed rapidly and the technology has become increasingly mature.

2. Calibration of the monitoring system
After the design of the dust concentration system is completed, different dust concentrations need to be measured and calibrated to verify the measurement accuracy and reliability of the system. The calibration of the dust concentration monitoring system is to use the dust spray device to generate dust in the laboratory. The actual dust concentration calculated by adding the dust mass and the device
volume in the dust spray device and the dust concentration monitoring system measurement results studied in this paper. A control test was performed. Figure 1 is a schematic diagram of a dust spray device.

![Figure 1. Schematic diagram of dust and fogging device](image)

Weigh the dust sample with a uniform mass particle size distribution with the balance, put it into the device, set the dust mass is $m$, and the device volume is $V$, then the dust concentration generated in the device is $\rho = \frac{m}{V}$. This concentration is used as the standard concentration, and the measurement data of the dust concentration monitoring system is compared with this value to obtain the system measurement accuracy.

In the test, 12 sets of standard concentration values were used, and the designed dust concentration system was used for measurement. In order to measure more accurate data, each set of data was averaged 20 times at the same concentration.

The following table is the test result of the dust concentration monitoring system. The data in the table is the absolute error value of the measurement result and the actual data. It is the relative error. It can be seen from table 1 that the maximum absolute error of the dust concentration monitoring system is 5.32%. The average error is 2.2%. When the measured concentration exceeds 1500g/m³, the value is relatively large. At this time, the accuracy of the instrument is significantly reduced.
The dust concentration values measured in the experiment are different from the actual dust concentration values. For example, 10 mg of pulverized coal is placed in a dust misting device. The concentration of the monitoring system is 68 mg/m³, and the actual value should be 100 mg/m³. Although the detected value is different from the actual value, the system fully meets the application requirements.

3. Monitoring system repeatability verification
Repeatability is also one of the important indicators to measure the performance of measuring instruments. Repeatability refers to the relative standard deviation (RSD), which is calculated from the standard deviation and average value of the test data, i.e., RSD = standard deviation / average.

The same kind of coal powder was used in the experiment, and the experiment was carried out continuously for three days. The test results are shown in table 2. The dust concentration value is the standard concentration of the dust spray device, and the measured concentration value is the
4. Error analysis of monitoring system

In view of the deviation between the above test data and the actual value, the factors affecting the measurement results of the dust concentration monitoring system are analyzed.

1) Light source fluctuation

In this paper, the dust concentration monitoring system is designed with the light source fluctuation in mind. The dual-optical differential optical path system is used in a targeted manner to minimize or reduce the influence of the light source fluctuation on the monitoring system. In the design of the power supply circuit of the semiconductor laser, in addition to the voltage regulator circuit composed of the LM1117 series regulator tube, a constant current source constant current drive module is specially added for the laser. However, these measures can only greatly reduce the influence of the fluctuation of the light source, and can not eliminate the fluctuation of the light source caused by other comprehensive factors inside and outside the instrument, and still affect the monitoring system.

2) Measurement window pollution

When the monitoring system monitors the dust concentration online, since the measuring window lens is always exposed to the dusty environment and the adhesion of the dust particles, the measuring window lens will adhere to some dust particles on the surface after working for a period of time, which will hinder the measurement. The propagation of the beam causes the beam received by the photosensor to be small. Directly affects the accuracy of the monitoring system. In order to avoid the impact of this problem on the monitoring system, it is necessary to add a special lens cleaning device to the measuring window lens, and perform strong wind cleaning on the window lens before starting the measurement and after measuring for a period of time. This is the follow-up work of this paper.

3) Environmental temperature impact

Temperature affects almost all measuring instruments, especially those using semiconductor devices, because temperature has a large influence on semiconductor devices, and in severe cases, the characteristics of semiconductor devices may change. In the dust concentration monitoring system of this paper, temperature changes will affect the performance of semiconductor lasers and photoelectric

| Measurement result of the system. | Table 2. Repeatability experiment |
|-----------------------------------|----------------------------------|
|                                  | March 20  | March 21  | March 22  | Repeatability |
|-----------------------------------|----------|----------|----------|--------------|
| Standard concentration mg/m³     | measuring | standard | measuring | standard | measuring | % |
| mg/m³                            |          | mg/m³    |          | mg/m³    |          | mg/m³ |
| 50                               | 51.6     | 50       | 53.3     | 50       | 53.9     | 3.2   |
| 150                              | 163.2    | 150      | 162.5    | 150      | 159.1    | 3.6   |
| 200                              | 209.7    | 200      | 205.9    | 200      | 211.7    | 2.1   |
| 250                              | 262.7    | 250      | 259.4    | 250      | 263.2    | 3.2   |
| 350                              | 349.5    | 350      | 365.2    | 350      | 372.3    | 5.4   |
| 500                              | 510.2    | 500      | 507.4    | 500      | 510.2    | 0.5   |
| 750                              | 735.1    | 750      | 760.2    | 750      | 754.7    | 2.9   |
| 1000                             | 977.8    | 1000     | 984.6    | 1000     | 973.8    | 2.4   |
| 1250                             | 1200.6   | 1250     | 1224.2   | 1250     | 1215.4   | 3.7   |
| 1500                             | 1420.2   | 1500     | 1426.6   | 1500     | 1442.3   | 4.1   |

In the laboratory, the monitoring system carried out three consecutive days of dust concentration detection experiments. The statistical data are shown in Table 2. The data are analyzed and calculated. The results show that the maximum measurement repeatability of the monitoring system in this paper is 5.4%, which meets the repeatability requirements of the instrument and has good repeatability.
sensors. The previous chapters describe the shortcomings of semiconductor lasers that are susceptible to temperature. Temperature changes can cause the exiting light of a semiconductor laser to fluctuate, which is what we are most worried about. Similarly, when the photodetective sensor is in a temperature fluctuation environment, its output detection signal also fluctuates. The light source and photodetective sensor are the most important part of the monitoring system, and the temperature change just affects its stable operation. Solving this type of problem can take measures from the source, using a constant temperature system to provide a stable temperature environment for the acquisition system and reduce its impact in the monitoring system. However, this increases the complexity and cost of the system and is not practical. In addition, we can also use the software to perform temperature correction to correct the system measurement results, and achieve the measurement results in line with the actual measurement without increasing the system structure.

4) Other aspects
In addition, distribution of dust particles, the moisture in the air, the refractive index of the dust particles and the speed of the pumping speed of the pump will cause errors in the measurement results of the monitoring system.

5. Conclusion
The system designed in this paper carries out data measurement and calibration. A large number of experimental results show that the system meets the design requirements in terms of reliability and accuracy. At the same time, the monitoring system also has certain errors. In this regard, this chapter analyzes the errors and causes of the system. In the subsequent experiments, the system was improved to improve the accuracy and reliability of the system measurement.

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