

## Dust arising mechanism and dust reduction technology of open-pit coal mine using water and sediment reduction effect

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### ABSTRACT

The purpose is to provide scientific and effective dust control measures, control the dust source from the root, and formulate practical control measures. Based on the effect of water and sediment reduction, the dust arising mechanism and dust reduction technology of open-pit coal mine are studied. Based on the dust arising mechanism, the QS spray system is introduced in detail and its technical design is described in detail from three aspects: design and composition, spray particle size range and dust reduction effect, and the automatic spray and dust reduction reliability when the dust concentration exceeds the limit. Therefore, dust control is a long-term and arduous task, and the core method to control its harm is to use efficient measures to eliminate the dust that has been produced in the atmosphere. It is the basis of coal mine dust control to improve the scientific dust control mechanism.

*Keywords:* Water and sediment reduction effect; Coal mine; Dust arising mechanism; Dust reduction technology

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### 1. Introduction

With the development of social economy and the improvement of people's living standards, the demand for energy in the whole society is increasing. As China's main energy, the degree of coal development and production industrialization is increasing year by year, but it also brings more and more serious dust pollution, which gradually makes all coal mines and environmental protection agencies pay attention to it, and successively carry out a series of dust prevention and dust reduction related work [1]. In the mining of open-pit coal mine, the most important is dust pollution, which generally comes from dumping, blasting and other operations. In particular, coal production, processing, loading and unloading operations are the key links of dust production. Air pollution in the production process of open-pit coal mine is a thorny problem that cannot be ignored. Due to the strong volatility and diffusion

of dust, it is easy to damage the surrounding environment and ecological resources, which seriously restricts the development of coal industry [2,3]. Therefore, dust control has become the key to prevent air pollution and improve the environmental quality of the factory.

Based on the effect of water and sediment reduction, the mechanism of coal dust generation mechanism and intelligent spray dust reduction technology are introduced. On the basis of dust concentration, the technology sets the dust concentration alarm value and upper limit value to realize automatic overrun spraying and reduce dust concentration. The QS type sprayer is designed according to the atomization and dust reduction mechanism and the gas water mixing atomization theory. It can adjust the droplet size according to the field conditions and cover the dust producing area. After the test, the conclusion is that by setting the upper limit control value and alarm value of the dust concentration of the intelligent dust reduction system,

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the dust prevention equipment can be effectively controlled, so as to achieve the purpose of reducing the dust concentration; the QS sprayer adopts gas water sprayer, which improves atomization effect to a certain extent, makes the spray particle size controllable, and can be also adjusted accordingly according to the specific conditions at the scene.

The research innovation is that the dust reduction technology realizes the overrun automatic warning and function of spray, which makes the atomization combined with the particle size of the dust. Compared with other methods, it realizes intelligent spray, reduces the dust concentration, avoids the coal dust explosion, and has achieved certain results in the great reduction of water and sand. It also effectively prevents the occurrence of pneumoconiosis in miners.

## 2. Method

### 2.1. Dust arising mechanism of coal mine

In coal mining, there are many reasons to produce dust. For example, mining, drilling, blasting and so on will lead to the rampant dust. However, due to the different conditions of coal and rock, the mining methods and ventilation methods are not the same, and the amount of dust produced also varies greatly; the output of the same mine varies greatly with time and place [4]. Generally, in the current dust control technology background, the proportion of dust produced in each production stage is about as follows. Mining operations account for 40%–85%; the proportion of excavation is between 20% and 40%; the proportion of dust in the construction site is between 10% and 20%; others account for about 2%–5%. With the improvement of mechanization, the amount of dust will increase, so the prevention and control work is more important.

### 2.2. Properties and characteristics of dust in open-pit coal mine

Dust is a kind of fine particles with a diameter of about 10  $\mu\text{m}$ . It has a layer of hydrophobic air film on its surface, which makes it difficult to combine with the water vapor in the air. As a result, the dust cannot settle and can only be suspended in the air. Dust is produced by coal. The density of coal is small, the density and dispersion of dust particles are small, and the surface area of particles is large, which can absorb more oxygen molecules. Therefore, the oxidation degree of dust particles is high, which increases the possibility of dust inhalation into human lungs [5]. The dust is mainly distributed in the form of dispersion. In the process of coal mining, dust is dispersed in the air and has a wide range of activities. It can also absorb harmful gases and flow and disperse with the air.

The moisture absorption of dust is obvious. In the process of coal mining, most of the dust is produced by the coal itself. Since the coal itself has strong adsorption, most of the dust will naturally carry this characteristic, and some dust also has water absorption. Because of this, the characteristics of dust in the atmosphere are used, and more humid things are added in the atmosphere to remove the dust in the atmosphere, which provides a scientific and

simple method for the effective control of dust pollution in open-pit coal mining [6]. Dust in the atmosphere generally contains sulfur dioxide, and it is extremely harmful to human health. Because of the long-term inhalation of dust containing harmful substances in coal mine workers, the possibility of lung related diseases increases, which even leads to lung cancer and other persistent diseases.

Dust can self-ignite. Coal itself is combustible, so when it is in the form of powder, its surface area is significantly increased, and its oxidation capacity is greatly improved. When the dust is oxidized, the internal heat cannot be released properly, but the oxidation reaction accelerates automatically when the heat is stored and heated, resulting in its spontaneous combustion. According to the temperature of spontaneous combustion, it can be divided into two categories. One is that when the self-ignition temperature is higher than the ambient temperature, the reaction can only be caused by heating; The other is when the self-ignition temperature of the object is lower than the ambient temperature, it can self-ignite even without heating. This kind of dust is harmful and easy to cause fire [7].

### 2.3. Dust reduction technology of QS spray system

The intelligent spray dust reduction system is mainly composed of QS sprayer, DFH20/7 centralized control box and connecting water pipes and air pipes. Moreover, after the atomization technology of air-water mixing is combined, the spray system of various spray devices is designed. The spray system is composed of multiple nozzles, and its design principle is based on gas water mixing atomization and atomization correlation dust reduction mechanism [8]. In order to apply to different situations, the designed atomizing sprayer is made up of three nozzles. The spray direction can be adjusted according to the needs, and the atomization mixing structure is used inside. By adjusting the gas-water ratio, the particle size distribution of each nozzle can be adjusted according to different dust conditions, so as to achieve the best dust removal effect.

Centralized control box. The central control box is mainly composed of electric ball valve, manual valve and filter. Electric ball valve is an electric valve which controls the opening and closing of water or air channel by rotating the ball. Its components are digital logic and direction control circuit, current sampling circuit and working state indication circuit. The electric ball valve receives the signal from the sensor when the dust concentration is greater than the limit value. At this time, the current sampling circuit starts to monitor the orientation of the electric ball valve, so as to control the opening and closing of the ball valve [9]. The indicator light determines the working condition of the electric ball valve. The manual ball valve in the centralized control box controls the particle size distribution range of the spray particles, adjusts the gas-water ratio of the spray system, and improves the dust reduction efficiency of the spray system. The function of the filter is to filter the water flow so as to prevent the nozzle from clogging.

Control box. KXJ1-127/36 control box is used to control electric ball valve or solenoid valve in open-pit coal mine. It uses integrated circuit and is equipped with a set of integrated circuit board. The integrated circuit board is

composed of digital circuit, relay and oscillator. After the control box receives the signal band of the sensor, the opening and closing of the solenoid valve of the main control circuit in the control box will be controlled by the relay [10]. The core values of the control box are as follows. The power supply voltage is 36V AC or 127V AC, and the control distance is more than 5m. The transformer reduces the AC connected to itself to 34V, and 34V AC becomes DC. The input end of the relay is connected with the relay, and the output end of the relay is connected with the electric ball valve. At this time, the power on and power off of the relay is controlled by the control terminal of the substation. When the concentration of dust exceeds the set limit, the system host sends instructions to substation signals and substations make corresponding actions, and controls the QS spray system by controlling the switch of the electric ball valve.

**3. Design of intelligent spray dust reduction technology**

*3.1. Design basis and composition*

With the performance value of water mist dust as a reference, through the diffusion and movement speed of fog particles as well as the shape and pressure of fog flow, it can be known that the higher the pressure is, the smaller the fog particles are, the faster the speed is, and the larger the volume of fog flow is. According to the mechanism of dust reduction, aggregation and diffusion, the best relationship between the diameter of dust and the diameter of fog particles is shown in Eq. (1).

$$d_0 = d_1 \cdot \frac{pv}{(18\eta \cdot \mu)} \tag{1}$$

In Eq. (1),  $d_1$  is the dust diameter with the largest proportion on site;  $p$  is dust density;  $v$  is air velocity;  $\eta$  is the air viscosity coefficient;  $\mu$  is viscosity of water;  $d_0$  is the largest diameter of fog particles.

The diameters of dust and fog particles present log-normal distribution. In the field measurement of dust diameter and density, Eq. (1) can be used to determine the optimum diameter of dust particles in the field.

According to the mechanism of dust reduction, the effect of dust reduction is largely affected by the diameter of fog particles. If the water droplet is small, the density of the water scattered in the atmosphere is large, which makes the probability of contacting dust is large, and the dust catching effect is better. However, if the diameter of water is too small, the weight of dust particles will not increase greatly after contacting with dust particles, which makes it difficult to settle down in the air. Besides, the water is also taken away by the wind and evaporated, which is not conducive to dust capture [11]. According to the experience and measurement, the optimum particle size of fog particles is determined to be between 50 and 150. Through the comparison of the scheme and the indoor test, the air water atomizer is selected to achieve the best dust removal fog particle size.

Fig. 1 is a schematic diagram of the intelligent spray dust reduction system.

The operation principle of GCC500 dust concentration sensor in the system is to use light scattering to monitor the

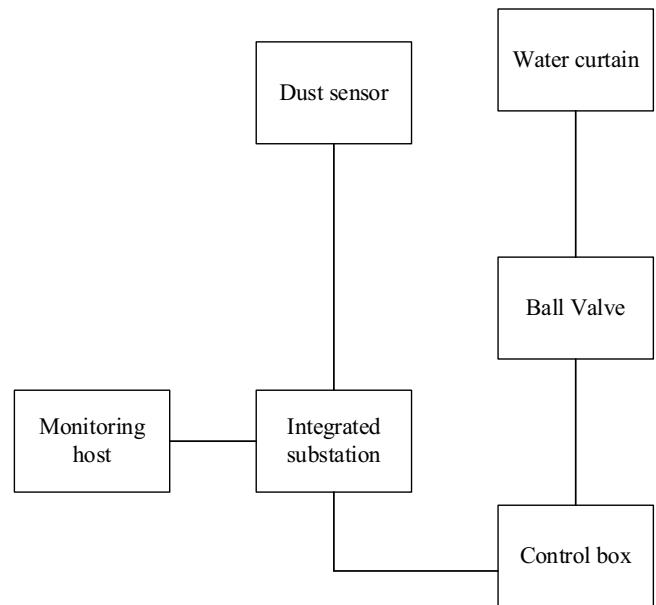


Fig. 1. Schematic diagram of intelligent spray dust reduction system.

dust concentration, and then output the signal corresponding to the detection system; the system controls the solenoid valve automatically by setting the value of overrun and early warning, and automatically detects the value when the detection value exceeds the set value, so as to realize the automatic control of the spray device. While the dust concentration is reduced, it also improves the working environment [12].

GCC500 dust concentration sensor used in this project is composed of light source, dust measurement system, air extraction system, control circuit, photoelectric converter and dust filter. The sensor is used to monitor the data at the working site, and constantly output the current signal corresponding to the monitoring system for the system to process. The characteristics of GCC500 dust concentration sensor are that it can quickly and accurately measure the data, flexible and stable performance, can set the dust scattering coefficient by itself, and can also display the dust concentration.

The operation process of the system is as follows. Based on the influence of the film pump, the dust flow enters the light scattering detection chamber through the dust removal port. The scattering angle is 90° through the illumination of the laser light source and the detection of the detector. Under certain conditions of dust properties, the scattered light intensity of dust increases with the increase of dust concentration.

$$C = K \cdot I \tag{2}$$

In Eq. (2),  $C$  is the dust concentration,  $\text{mg}/\text{m}^3$ ;  $I$  is the laser intensity;  $K$  is the light scattering proportion coefficient.

*3.2. Spray droplet size range and dust reduction effect in spray dust reduction system*

The particle size distribution of the spray dust reduction system has a great influence on the dust reduction

efficiency of the system. In the experimental system, the particle size range of the intelligent spray dust reduction system under different gas-water ratio conditions is tested by the Malvin particle size measuring instrument. Table 1 shows the distribution of fog particle size with different gas-water ratio under the same pressure. Besides, the spray efficiency of different gas-water ratios under the same dust is tested. Dust concentration of the spray before and after spraying is measured by the dust detector, and the dust removal efficiency of the spray dust removal system is investigated. Table 1 presents the specific test results.

The results of Table 1 show that when the spray particle size of the spray dust reduction system is closer to the median diameter of the captured dust particle, the dust removal efficiency is higher.

3.3. Reliability of automatic spray and dust reduction when dust concentration exceeds limit

The intelligent spray dust reduction system has completed the reliability test in the laboratory. According to the monitoring data of the monitoring system, the probability of failure is low, but it needs to carry out deep test in the actual use. By adjusting the gas-water ratio, the intelligent spray dust removal system can reduce the dust removal efficiency by more than 30%, and achieve accurate

Table 1

The particle size distribution of different gas-water ratios and the test results of the efficiency of spray dust reduction for the same coal dust

Gas-water ratio (volume ratio)	Distribution range of fog particle size, $\mu\text{m}$	Dust reduction efficiency, %
0.7	90~140	25
1.0	70~110	31
1.2	40~90	39
1.5	30~85	46

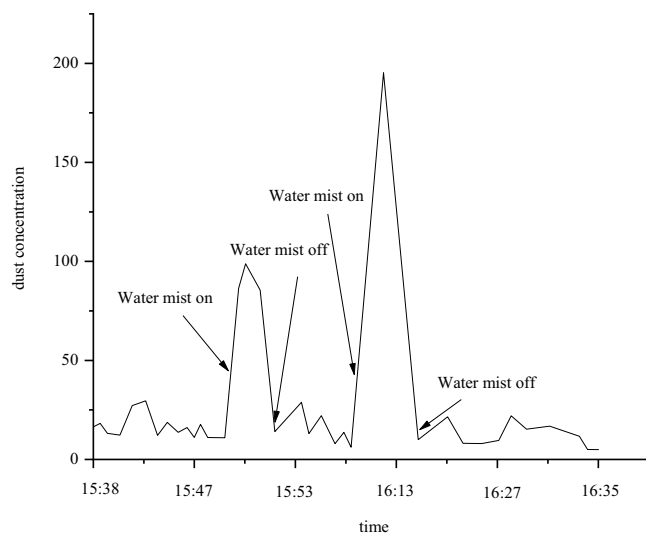


Fig. 2. Monitoring curve of dust sensor on March 16.

monitoring of the dust concentration. When the dust concentration exceeds the defined value, the system automatically sprays [13,14].

Water mist automatic control. To a certain extent, water mist automatic control has met the basic requirements of coal mine for dust reduction, and has achieved good reputation in many mines. Based on the situation at the scene and the results of the measurement, the concentration of dust required on the system mainframe for opening the spray is  $33 \text{ mg/m}^3$ , and the dust concentration value required for closing the spray is  $15 \text{ mg/m}^3$ . It means that when the concentration of dust monitored by the system is greater than  $33 \text{ mg/m}^3$ , electric ball valve will automatically open and start spraying to reduce dust. When the dust concentration monitored by the system is less than  $15 \text{ mg/m}^3$ , the electric ball valve will automatically shut down and stop spraying [15]. Figs. 2–4 are the change curves recorded after downhole observation.

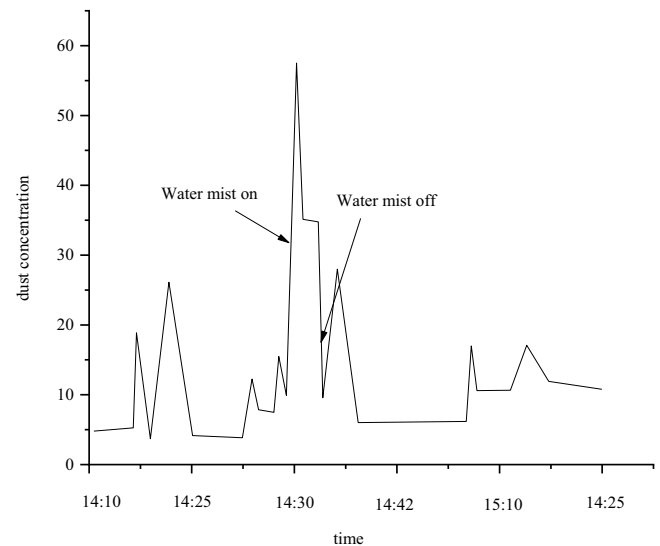


Fig. 3. Monitoring curve of dust sensor on March 23.

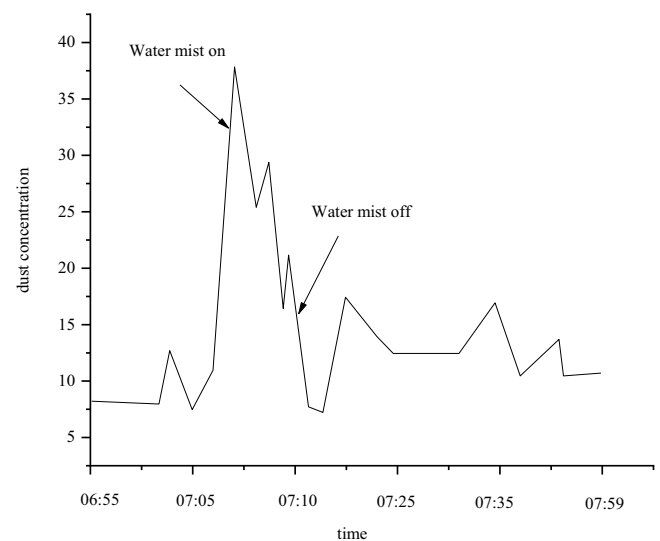


Fig. 4. Monitoring curve of dust sensor on March 28.

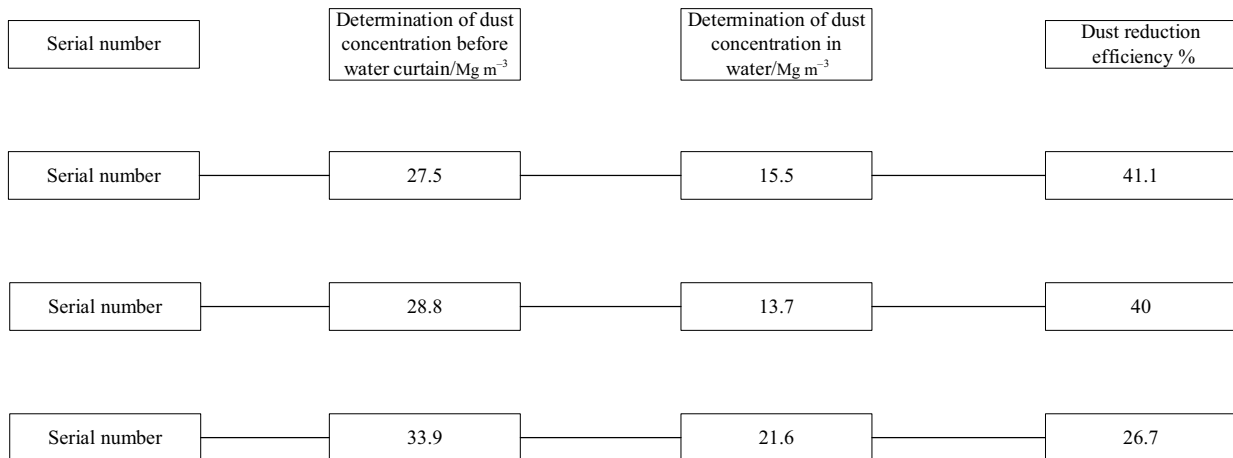


Fig. 5. Statistical chart of test results of spray dust reduction effect.

The above figures show that the advantage of using the dust concentration sensor is that it can readily achieve spray dust reduction at any time. Because of the intelligent control of the opening and closing of the spray, it saves water resources to a certain extent.

Spray effect test. A dust sampler is used to monitor the dust concentration before and after the system and the dust reduction effect after the system is sprayed. Fig. 5 presents the detailed value. Therefore, the dust removal efficiency of QS spray system is high, and the final result is more obvious [16–22].

#### 4. Conclusion

- By setting the upper limit control value and alarm value of the dust concentration of the intelligent dust reduction system, the dust prevention equipment can be effectively controlled, so as to achieve the purpose of reducing the dust concentration. In addition, other types of dust prevention equipment can be further controlled by various drivers, so as to minimize the labor intensity of workers, save manpower and material resources, reduce the waste of water resources, reduce the dust accumulation intensity, and improve the working environment.
- The QS sprayer adopts the gas water sprayer to improve the atomization effect to a certain extent, so that the particle size of the spray can be controlled, and it can also be adjusted according to the specific conditions at the scene. The original solenoid valve of the system is replaced by the current electric valve, and the effect is very good. Besides, the problem of easy blockage is solved.

Coal mine dust prevention work is a strict work. The operators must have a high degree of dust prevention and dust reduction consciousness; the coal mine must have a sound supervision and management system, which must be realized in the work. The specific implementation requirements of coal mine dust control are as follows. The concentration of particulate matter in the atmosphere must be monitored by professionals; the

specific implementation of prevention and control measures should be checked every day; dust pollution prevention education should be done well; the problems found should be solved immediately to ensure the continuous operation of the treatment system; the dust pollution should be monitored every day, and the concentration change beyond the relevant standards and regulations should be dealt with in time. Coal mines should strengthen the supervision and management of dust prevention to ensure the safe production of coal mines. Perfect management, supervision, prevention and control mechanism has a very important impact on the safety production of open-pit coal mine, and also has important significance for the physical and mental health and personal safety of operators.

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