Overview of Downhole Spray Dust Removal Technology

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Abstract. Spray dust technology is one of the main methods of the coal mine dust prevention, comprehensive dust spray technology are summarized, the principle of the spray nozzle, water quality, spray dust system automation affect efficiency: common pressure type nozzle when the nozzle pressure and aperture around 8 MPa and 1.5 mm respectively when the dust efficiency is higher, magnetized water and the addition of wetting agents to further improve the efficiency of dust, spray dust system automation and intelligent development promoted the improvement of the downhole working conditions and improve work efficiency, and through the comparison of different nozzle type, compare the advantages and disadvantages, puts forward the future development direction of the nozzle.

1. Principle of spray dust removal
The mechanism of spray dust removal [1] is mainly that water under the action of high pressure nozzle forms tiny fog drops in collision and contact with dust particles in the air in accordance with the jet atomization mechanism, thus achieving the purpose of dust removal. The process of spray dust removal is mainly inertia collision, interception, diffusion, gravity settlement, and electrostatic adsorption and eddy current condensation. The inertial impact is a dust particle with particle size greater than 0.5 \( \mu m \), because its inertial action cannot bypass the fog drops, it will collide with the fog drops and coalesce. When the dust particle moves towards the droplet along the gas flow line, if the distance between the air flow line and the surface of the droplet is less than the radius of the dust particle, the dust particle will contact with the droplet and be trapped. Brownian diffusion is a process in which dust particles with particle size less than 0.1 \( \mu m \) are impinged on by gas molecules in the air to make irregular movements and are captured by droplets. Spray water can be charged when it is ejected by high-pressure nozzle. Dust particles will also generate a certain amount of charge when they collide and rub with surrounding objects during floating. It makes the dust particles more easily adsorbed and captured by the droplet. Under the effect of high pressure spray, vortex airflow formed in the working face space intensifies the fluctuation velocity and amplitude of dust movement, increases the chance of collision with droplets, forms eddy condensation, and improves the dust removal efficiency of spray dust removal.
2. Optimization of spray dust device
At this stage, the spray dust device because of its wide coverage, and better effect of dust has deep mine dust areas, but with the improvement of mechanization degree and to people's physical and mental health and the importance of the working environment and requirements unceasing enhancement, the spray dust dust removal efficiency and practical economy put forward higher requirements. Optimizing the nozzle and changing the water quality can further improve the efficiency of dust removal. The application of various sensors and wireless communication also makes the underground coal mine spray dust removal system more intelligent and practical. The optimization of atomization dust removal system is illustrated by the optimization design of nozzle, improvement of intelligent and automatic form of raw material and device.

2.1. The optimization of nozzle
In accordance with the relevant experiment [2], small diameter nozzle atomizing nozzle atomization effect is more obvious than large diameter nozzle, spewing droplet diameter smaller, and the combination of respiratory dust is more efficient, but small diameter nozzle easily blocked by the impurities in the water, causing water damage and reduce the nozzle, on the premise of both practical and efficient, the inner diameter of the nozzle with 1.5 mm - 2 mm advisable.

The higher the nozzle pressure, the wider the spray spraying range, the higher the uniformity of droplets distribution, and the better the dust capture efficiency [3]. However, if the pressure is too high, it will not only increase energy consumption, but also damage the nozzle, causing fatigue and reducing its service life [4]. The downhole nozzle pressure should be about 8MPa.

Pressure nozzles are widely used in underground coal mines [2]. Comparatively, the dust removal efficiency of swirl vane nozzles is higher than that of spiral and tangential pass nozzles. However, pressure-type spray is relatively high in providing pressure, and an efficient booster pump can be used to convert and provide the required pressure, making its control simpler and structure more reliable [5].

Most of the nozzle materials used in downhole in China are stainless steel and copper. In recent years, stainless steel and copper are used as nozzle materials.

2.2. Improvement of raw water for spray dust removal
Most downhole coal dust has strong hydrophobic [7], when the droplets are combined with coal dust has certain resistance, by joining in the water wetting agent to reduce the surface tension of water, particle diameter decreases, and make it easier for droplets are combined with coal dust, improve the efficiency of dust [8], but for the kinds of wetting agents [9] and the matching is still in the test phase, and wetting agent cost is higher, is not used widely in the underground dust [10]. The raw water is magnetized by the underground magnetization device, which can break or reduce the bond Angle of some hydrogen bonds contained in the water and reduce the surface tension and contact Angle of the
water, thus achieving better dust removal effect [11]. In order to further improve the dust removal effect and reduce the cost, magnetized water and coal dust wetting agent were used for dust removal, with a dust removal rate up to 94% and a more obvious effect on respirable dust [9].

2.3. Optimization of spray dust removal system
According to the existing research content [12-16], downhole automatic detection mainly senses the situation and transmits signals to the control unit through dust concentration sensor and infrared sensor. The main principle of dust concentration sensor is the principle of light scattering. Dust of different properties has different scattering effects on light. The scattering degree of light increases with the increase of dust concentration. The electric signal is transmitted to the control unit by the dust concentration sensor, and the control unit turns on or off the spray switch according to the transmitted dust concentration signal to control the dust concentration within a reasonable range. The infrared sensor transmits the signal to the control unit by sensing the passing of personnel or the moving position of the shearer. The control unit turns off the spray when there are pedestrians, and turns on the spray when there are no pedestrians, and reasonably turns on or off the nozzle according to the position where the shearer needs dust removal. Sensors and automatic control devices are part of the downhole control system, which provides comprehensive analysis and detection of dust concentration and operation through signal collection, information processing and information feedback. The application of dust concentration sensor and infrared sensor makes the spray dust removal system control the spray switch according to the actual needs. Make the working environment of workers more comfortable, avoid spray water to wet clothes, and can save water, achieve good effect of spray dust.

3. Comparison of different nozzle types
The main factor affecting the dust removal effect of spray is the nozzle. The dust removal effect and application of different types of nozzles are different. The advantages and disadvantages of various nozzle types are analyzed to clarify the applicable conditions and development direction of various nozzle types.

Table 1. Comparison of advantages and disadvantages of different nozzle types

| The nozzle type          | advantages                                                                 | disadvantages                                                                 |
|-------------------------|---------------------------------------------------------------------------|-----------------------------------------------------------------------------|
| Pressure nozzle         | Pressure nozzles are commonly used downhole and have a wide range of adaptability, among which cyclone vane nozzles have the best dust removal effect [17]. | The pressure nozzle has a high requirement for water pressure, large water consumption and low efficiency for the collection of respirable dust. |
| Pneumatic atomizing nozzle | The air-water pressure of spray is the main influencing factor, and the pressure requirement is not high. | Factors affecting efficiency such as gas-water flow ratio lack of research and are not easy to adjust. |
| Supersonic nozzle       | Supersonic nozzles have better dust removal performance than traditional nozzles, and the dust removal efficiency of respirable dust is greatly improved. | Due to the limitation of downhole conditions, the application of downhole spray dust removal is limited. |
| Bubble atomizing nozzle | Bubble atomizing nozzles achieve atomization by overcoming liquid surface tension and have little requirement for nozzle aperture, which can reduce blockage and wear of equipment [18]. | Bubble atomizing nozzle needs to form a stable bubble flow to achieve better atomization effect [20]. |
| Electrostatic nozzle    | The electrostatic effect of the nozzle is to make the droplet with a certain charge, so that the droplet and the dust particle can be combined through coulomb force, which is more targeted and adherent, and the dust removal effect is better [19]. | Electrostatic nozzle can improve dust removal efficiency by charging fog drops with high voltage electrode. It is not suitable to use electrostatic nozzle in underground working environment, especially in high gas mines. |
4. Conclusion
(1) The level of the spray dust dust efficiency are mainly with the nature of dust particles, nozzle aperture, nozzle pressure, water quality and water and so on, the pressure of the common type experiment it is concluded that the most reasonable spray nozzle parameters inside diameter and spray pressure is 1.5 mm and 8 mpa, adding in the raw water wetting agents or make magnetized water can reduce the surface tension of the water, improve the efficiency of dust removal, but wetting agent cost is higher, and the test in the early stage, the application is not common.

(2) With the development of various sensors, the switch control of spray dust removal also changes from manual control to automatic control, and the control monitoring system makes timely analysis to facilitate people's access and inspection. Greatly improve the underground dust removal efficiency and work efficiency.

(3) Through the comparison of various nozzles, it can be seen that the new nozzles, such as supersonic nozzles, electrostatic nozzles and bubble atomizing nozzles, have a better dust removal effect than the traditional nozzles. However, there are still some problems, such as the lack of in-depth research on the influencing factors of the efficiency of nozzles and the greater impact from the environment. Different environments should focus on different spray dust removal modes, further improve the action mechanism and influencing factors of various nozzles, learn from each other, and make the spray dust removal system develop towards the direction of high efficiency and wide adaptability is still the mainstream of future research.

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