Experimental Research on Atomization Parameters of High Pressure Nozzle

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Abstract. The effect of wind speed on the nozzle effective water volume and distribution uniformity and the fog particle size was studied. The results showed that when the fog particle size and the dust particle size distribution range were close, the dust reduction effect was the best. With the increase of spray pressure, Under the influence of the wind flow, the effective water flow of the nozzle is 80% of the effective water without wind flow, as the wind speed increases, the spray range and the spray coverage area decrease greatly. Based on the experimental results, the dust-reducing efficiencies of total dust and respirable dust concentration were 91.1% and 90%, respectively, after the dust was sprayed by the preferred nozzle at the unloading point of the Xiadian Gold Mine unloading station.

1. Introduction
Spray dust reduction is one of the most widely used technologies in mine dust control systems, and nozzles are the core component of spray dust reduction technology, which directly affects the spray dust reduction effect. The current research on the performance parameters of nozzles is basically based on no wind or almost no wind. When spray dust suppression technology is used in underground working faces or roadways, it is affected by wind current. Practice has proved that the atomization performance parameters of the nozzle change significantly under different wind speed conditions. Therefore, the atomization performance parameters of the nozzle under no wind or almost no wind have little meaning for the selection of nozzles, which leads to the selection of nozzles. Lack of effective support from theory and experimental data. Therefore, according to the environmental parameters of different wind speed conditions, this article studies the influencing factors of the nozzle atomization performance parameters to guide the engineering application under different industrial and mining environmental conditions.

2. Test system and test method
2.1. Test system
In order to truly simulate the atomization performance parameters of the nozzles under mine environmental conditions, the effect of wind speed on the effective water volume and distribution uniformity of a single nozzle, as well as the particle size of the mist particles, was carried out in the laboratory simulation roadway. The wind speed was changed by adjusting the air volume of the fan. The effective water volume, water volume distribution uniformity, average mist particle size and water
consumption of the spray system are obtained, and the effectiveness of each nozzle under different wind speeds, mining heights and pressures is obtained. The test analysis system is shown in Figure 1.

![Figure 1. The test system diagram.](image)

2.2. Testing method

From the perspective of engineering application, this experiment is based on MT/T 240-1997 "General Technical Conditions of Nozzles for Dust Suppression in Coal Mines", combined with relevant literature for preliminary selection, and select the more common nozzle series in engineering applications, mainly including longer range. There are 32 types of stainless steel nozzles in four categories: G series high-pressure nozzles, S series solid cone nozzles, PZ series solid cone nozzles, and SS series solid cone nozzles, which are far and with better atomization effect. They are numbered and screened. According to the actual situation of mine ventilation and spray application, the nozzles tested under the conditions of wind speeds of 0m/s, 1.5m/s, 2.5m/s, and 3.5m/s respectively at 6MPa, 8MPa, 10MPa, 12MPa Effective water volume, conditional atomization angle and effective range.

When testing water consumption and effective water volume, the nozzle sprays vertically downwards, and the wind flow is perpendicular to the nozzle outlet direction. Use a water container to test on the axis of the spray vertical to the roadway. Place a cross meter on the ground directly below the nozzle for cross measurement. The vertical projection points of the center of the instrument and the center of the nozzle coincide, and the test system is shown in Figure 2.

![Figure 2. The system diagram of effective water test.](image)

The conditional atomization angle of the nozzle is tested according to the test method specified in MT240-1997. The distance between the two intersections of the spray boundary is L, which is defined in accordance with the standard definition of the conditional atomization angle (the vertical line of the
water mist center line at 500mm from the nozzle. The angle between the two intersections of the boundary of the mist and the center of the nozzle), the conditional atomization angle of the nozzle is calculated as: \( \theta = 2 \arctan L / (2 \times 500) \). The effective range is the distance between the deviating point of the spray and the nozzle under the influence of wind current. The test method is shown in Figure 3.

![Figure 3. Effective range and atomization angle test chart.](image)

### 3. Analysis of spray parameter test results

#### 3.1. Spray particle size analysis

The droplet size is the result of the combined effect of many factors such as pressure, wind speed, and nozzle aperture. According to the four main factors of nozzle outlet diameter, nozzle length, spray pressure and nozzle distance, the orthogonal test method is used to obtain the difference of each factor to Dv(10)(\( \mu \)m), Dv(50)(\( \mu \)m), Dv(90)(\( \mu \)m), D[4 3](\( \mu \)m) and D[3 2](\( \mu \)m) are shown in Figure 4.

![Figure 4. Contribution rate of each factor to each indicator.](image)

Fog can be derived from the contribution rate of each factor to each index in the range analysis and significance test. The influencing factors of the spray particle size distribution are the distance from the nozzle, the nozzle diameter, and the spray pressure. The length of the nozzle only affects Dv(10). Certainly affect. Therefore, in the application of spray dust reduction engineering, after the initial selection of nozzles, the nozzle installation position should first be determined according to the...
field application, that is, the distance between the dust source point and the nozzle, and then the nozzle aperture, and finally the spray pressure should be appropriately adjusted as needed. At the same time, the particle size increases with the increase of distance, decreases with the decrease of nozzle diameter, and decreases with the increase of spray pressure. The effect of nozzle length is not obvious. The main reason is that as the spray distance increases, the speed of the mist particles decreases, and the small mist particles are continuously swallowed by the large mist particles, resulting in larger particle size and reduced number of mist particles. The smaller the nozzle diameter, the liquid is broken into mist particles. The stronger the internal turbulence, surface tension, and the mutual extrusion and shearing forces of the surrounding media, the smaller the particle size. But the mist particles are too fine to evaporate and lose their effect. Tests show that the dust reduction effect is best when the diameter of the mist particles is close to the distribution range of the dust particle size. Therefore, on the basis of fully considering the distribution range of dust particle size and the proportion of respirable dust at different work sites, select nozzles that can produce similar dust particle size distribution and proportion of respirable dust.

3.2. Analysis of nozzle atomization performance parameters

Mine nozzles are used when there is wind, and the air flow will affect the spray range, effective water volume, nozzle coverage and other atomization performance parameters to varying degrees. After the nozzle is optimized based on the spray particle size analysis in the test, the spray range and spray coverage area are greatly affected by spray pressure and wind flow. Therefore, the test was conducted under different wind speeds and pressures, and the rules of spray range influence are shown in Figures 5 and 6, and the spray coverage area influence is shown in Figure 7 and 8 shown.

![Figure 5](attachment:image1.png)

**Figure 5.** The nozzle range variation with pressure of 1.5m/s wind speed.

![Figure 6](attachment:image2.png)

**Figure 6.** The nozzle range changes with wind speed of 8 Mpa pressure.
Figure 7. The nozzle spray coverage area with pressure diagram of 1.5m/s wind speed.

Figure 8. The spray of nozzle cover area with wind speed of 8 Mpa pressure.

It can be seen from Figures 5~8 that as the spray pressure increases, the spray range increases, the spray flow rate increases, and the spray coverage area also slightly increases, mainly because the spray pressure makes the droplets have greater kinetic energy and speed, and the spray flow rate. At the same time, the pressure increases and the atomization angle decreases, the wind resistance increases, the air resistance decreases, and the shooting range is longer. The wind speed increases, the wind resistance increases, and the spray range and spray coverage area are greatly reduced (except for downwind spray). Through the experimental results, it can be concluded that the influence of wind speed on spray parameters is higher than the influence of spray pressure on spray parameters.

By testing the effective water volume, under the influence of wind flow, the spray flow rate at the maximum effective range of the spray under different experimental spray pressures of various nozzles is about 80% of the spray flow rate under the condition of no wind flow, that is, the wind flow causes the effective range to spray The flow loss is about 20%.

Therefore, in the application of dust suppression by spraying technology, the wind speed at the spray application site should be accurately measured, and the appropriate nozzle should be selected according to the nozzle parameter test results under the wind speed condition, and when the site conditions permit, try to avoid upwind spray.

4. Field application analysis

During the unloading of mine trucks in the unloading station of Zhaojin Group Xiadian Gold Mine, a large amount of dust was generated at the unloading pit. According to the on-site dust concentration test, in the middle of the unloading station, the total dust and respirable dust concentrations reached 350mg/m$^3$ and 120mg/m$^3$, resulting in serious dust pollution at this level unloading station. Due to the large area of the unloading station and not easy to be sealed, in order to prevent the spread of dust
generated by the unloading station, it is planned to adopt spray dust reduction measures for treatment. As the mine car unloads to the pit, it compresses the air in the pit, causing the airflow to diffuse out of the pit, forming a larger airflow, and the airflow escape velocity is about 1.5 m/s. When spraying downwards at the pit mouth, the airflow direction is opposite to the spraying direction, which is similar to headwind spray. Therefore, in order to prevent the dust from spreading, it is necessary to quickly capture the settled dust in a short time, and the water volume should not be too large to block the discharge pit. Adopt small flow, high pressure, large atomization angle, long-range anti-wind nozzle. According to the laboratory test data, when the wind speed is 1.5 m/s, the spray pressure is about 8 MPa, and the PZ nozzle with a range of 3 m is selected, and the dust concentration and dust reduction efficiency are shown in Table 1.

Table 1. The table of high pressure spray dust reduction efficiency.

| Type of dust | Sampling location | Original dust concentration (mg/m$^3$) | Dust concentration after high-pressure spray (mg/m$^3$) | Dust reduction efficiency (%) |
|--------------|-------------------|--------------------------------------|------------------------------------------------------|-----------------------------|
| Total dust   | 3m on the downwind side of the discharge port | 350                                  | 31                                                   | 91.1%                       |
| Breathable dust |                                     | 127                                  | 12.7                                                 | 90%                         |

According to the test results, when a suitable nozzle is used for high-pressure spray dust reduction measures, the total dust concentration on the downwind side of the discharge port has a dust reduction efficiency of 91.1%, and the dust reduction efficiency of respirable dust concentration is as high as 90%. The dust reduction effect is very obvious, and the dust reduction efficiency of respirable dust is very obvious. Also higher. Compared with previous engineering cases, the dust reduction effect of high-pressure spray is between 85% and 90%, mainly because the nozzle selection is unreasonable, and the spray effect is slightly lower due to the influence of wind current. Therefore, it has been proved by field application that the parameter test of the nozzle must consider the influence of wind flow, and the nozzle selection using the nozzle parameters tested under different wind speed conditions has very important guiding significance for the application of spray dust reduction technology.

5. Conclusion
Experiments on the influence of wind speed on the effective water volume and distribution uniformity of a single spray and the particle size of the mist were carried out in the laboratory simulation tunnel, and the field application was carried out in the mine unloading station, and the following conclusions were drawn:
(1) The spray particle size increases with the increase of the spray distance, decreases with the decrease of the nozzle diameter, and decreases with the increase of the spray pressure. The dust reduction effect is best when the mist particle size is close to the dust particle size distribution range.
(2) As the spray pressure increases, the spray range increases, and the spray flow increases, and the spray coverage area also slightly increases. With the increase of wind speed, the spray range and spray coverage area are greatly reduced, and the degree of influence of wind speed on spray parameters It is higher than the influence of spray pressure on spray parameters.
(3) Under the influence of wind current, the effective water volume of the nozzle is about 80% of the effective water volume under the condition of no wind current, and headwind spray should be avoided.
(4) Spray dust suppression technology needs to select suitable nozzles according to the wind speed value and nozzle parameter test results in the application of mine dust control. After the discharge point of the mine truck at the unloading station of Zhaojin Group Xiadian Gold Mine adopts the optimal nozzle to spray dust, the total dust and The dust reduction efficiency of the respiratory dust concentration is as high as 91.1% and 90%, respectively.
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