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Improvement and Research of Spray Dust Reduction Device for Highland Road Construction

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Abstract

This paper studies the dust problem encountered when road construction is carried out on the Qinghai-Tibet Plateau. Since the climate and topography of the Lhasa region is more representative of most of the Qinghai-Tibet Plateau, the author takes Lhasa as the research object, and analyzes the shortcomings of existing equipment used in the region by studying the characteristics of Lhasa as a typical plateau region, with the atmospheric pressure of Lhasa as the primary research idea. The results of spraying equipment with larger atomized particles under low pressure environment were obtained, which in turn provided new ideas for improving the currently available road construction spraying and dust reduction devices. It makes it more effective and suitable for road construction operations in the Qinghai-Tibet Plateau region.

Keywords: road construction, dust, spraying and dust reduction

1. Introduction

With the rapid development of China's economy and the acceleration of urbanization, the road construction to relieve traffic pressure on the original basis should be improved. The Qinghai-Tibet Plateau is located in the southwest border of China, covering an area of about 2.4 million square kilometers, accounting for 1/4 of China's national territory, and it is important to improve the traffic conditions and road construction in this region.

Because the average annual precipitation along the Tibetan plateau, the average annual temperature is low, the temperature difference between day and night, the average annual wind (wind speed > 40 / s) days up to 3 ~ 5 months, and high frequency, and more mountainous areas in Tibet, the road is mostly built in the valley valley, valley wind circulation is significantly stronger than other areas in China, valley wind circulation and weather scale background wind field superimposed to produce a strengthening effect is the main wind strength of the Tibetan plateau This is the main reason for the strong winds on the Tibetan Plateau. Strong winds are prevalent, so when road construction projects are carried out on the ecologically fragile Tibetan Plateau, it is inevitable to encounter strong winds and windy weather, which is very likely to cause a wide range of dust, and the construction of atmospheric pollution impact, the impact of dust pollution is more direct and more intense, so the dust not only affects the health of the staff, but also destroys the ecological and atmospheric environment of the plateau.

2. Existing Equipment Analysis and Improvement

2.1 Analysis of Existing Equipment

In the process of road construction, due to the construction materials and scenes, often the construction site will have more dust particles, these dust not only affect the health of the staff, the visibility of the construction site, but also on the road around the residents' lives, so people usually through the dust reduction device to reduce dust in the air, spray dust reduction technology is not only economical and practical, and the cost is relatively

Spray dust reduction technology is not only economical and practical, but also low cost and easy to use. At present, the spray dust reduction technology is not only used in urban road construction and tunnel construction projects, but also plays an increasing role in the purification of environmental air quality (Huang, J., Hou, C., & Li, X., 2022). The structure of spray dust reduction equipment currently used in highland areas is consistent with that used in inland areas of China, but such equipment still has the following problems in highland areas.

(1) The existing spray dust reduction devices for engineering construction, when dust reduction is carried out on road engineering construction sites, often due to the small dust reduction range of dust reduction devices, resulting in poor dust reduction effect of such engineering construction spray dust reduction devices for roads, which is not conducive to improving the practicality of dust reduction devices.

(2) Conventional spray dust reduction devices for road engineering construction, when dust reduction, the dust reduction strength of the dust reduction device cannot be adjusted, and the atomized particles are affected by factors such as plateau air pressure and air density, resulting in low dust reduction efficiency of the dust reduction device, which is not conducive to improving the experience of using dust reduction devices for road engineering construction.

2.2 Related Research

Spray dust reduction as the most efficient way to reduce dust, mainly through the following four ways to capture dust, and will be settled, so as to achieve the purpose of dust reduction.

(1) Through spraying, the humidity of the construction site environment rises, and the water gas gathers toward the center of the dust particles, increasing the mass and diameter of the dust particles, which is conducive to the collision between the dust particles, and when the dust particles collide with each other, the rebound force is relatively reduced because the surface is surrounded by water gas, and the dust particles will gradually settle down.

(2) Mass and diameter of dust particles, will be affected by their own inertia and gravity, the direction of motion will gradually deviate from the direction of the flow of wind, if you do not count the mass of dust particles, dust particles and the diversion of common movement, but the dust particles have a certain size, when the distance between the spray of water particles and dust particles center of mass is less than its radius, the two will stick together, so that the dust particles will be intercepted, this process is the interception of dust. process is interception and dust capture.

(3) For dust particles with diameters greater than 0.5 to 1 μm, the relative velocity of the water droplets and the diameter of the water droplets have a certain influence on the inertia coefficient of the dust, and the larger the inertia coefficient, the higher the probability of collision between the dust and the water droplets, which makes dust removal easier.

(4) Dust particles with a diameter of less than 0.2 μm mainly do Brownian motion, so that they can be trapped by diffusion and captured by water mist particles. (The principle of spraying dust reduction-Ningbo Haishu Yongcheng Shengda Environmental Protection Engineering Co.)

(5) For the atomization characteristics of the nozzle, can be measured by the number of droplets under a certain diameter, volume, mass of the cumulative distribution. For the existing situation, the droplet size distribution function is divided into two main categories, one is the empirical distribution function, and the other is the theoretical distribution function droplet particle size distribution (Chen, Q.-C., 2016).

The first is the description of the droplet particle size at the measurement point, the atomization of the formation of small droplets, although the diameter of different sizes, but its distribution has a certain pattern, can be characterized by the average particle size or cumulative volume percent (Cai, X., 2009), the formula is as follows:

$$d_{mn} = \left(\frac{\sum n_k d_k^m}{\sum n_k d_k^n}\right)^{\frac{1}{(m-n)}} \tag{1}$$

In the formula, n_k is the number of particles corresponding to the particle diameter d_k. When m=1, 2, 3, and n=0, the average particle size d_{10} d_{20} d_{30} are the average diameter, average area and average volume, respectively. And when m=3 and m=2, the d_{32} denote the Sauter mean particle size, respectively.

In order to assess the nozzle atomization quality and its atomization characteristics, the average diameter to express is not complete, more perfect practice should be expressed both the size of its particle size, but also the number or quality of different particle size droplets, which is the Rosin-Rammler empirical distribution function.

$$P_v(D) = \frac{1.368D}{D_v^2}.e^{\frac{-0.693D^2}{D_v^2}} \tag{2}$$

$$\int_0^D P_v(D)dD = 1 - e^{\frac{-0.693D^2}{D_v^2}} \tag{3}$$

In the formula, $P_v(D)$ is the frequency of occurrence of fog particles with diameter D.

And for the problem of DC nozzle atomization in still air, foreign researchers have studied and derived the following criterion relationship equation.

$$\frac{d}{d_0} = \frac{3.31}{M^{0.266}\mathrm{Re}^{0.1466}We^{0.1927}} \tag{4}$$

In the formula, $M = \frac{\rho_g}{\rho_f}$; $\mathrm{Re} = \frac{v_f d_0}{v_f}$; $We = \frac{v_f^2 d_0 \rho_f}{\sigma_f}$

$$\frac{d}{d_0} = \frac{3.9}{\mathrm{Re}^{0.25}We^{0.25}} \tag{5}$$

In the formula, $\mathrm{Re} = \frac{d_0 v_g}{v_f}$; $We = \frac{v_f^2 d_0 \rho_g}{\sigma_f}$

From the above equation (4) (5), it can be seen that the droplet size is related to the air density, and the droplet size will become larger when the ambient pressure decreases.

2) The effect of air pressure on the motion law of atomized droplets

The reduction of ambient pressure will affect the motion law of the droplets in the air. The drag force on the droplets during the motion can be given by the following equation

$$D = K_d v^2 \tag{6}$$

$$K_d = \frac{\rho_g C_D A_d}{2} \tag{7}$$

In the formula, D is the air resistance to the mist droplet. ρ_g is the air density; C_D is the traction coefficient; A_d is the cross-sectional area of the mist droplet; v is the relative velocity of the droplet to the air.

Since the air buoyancy force is small relative to the traction force, the air buoyancy force is ignored, and according to Newton's second law of motion law, the equation of motion of the mist droplet can be expressed as:

$$\begin{cases} m_d \frac{dv_x}{dt} = -\frac{v_x}{v} k_d v^2 \\ m_d \frac{dv_y}{dt} = m_d g - \frac{v_y}{v} k_d v^2 \end{cases} \tag{8}$$

In the formula, m_d for mist droplet quality; The traction coefficient is 0.44

The trajectory of the droplets on the fog cone surface at 0.06Mpa calculated from the above equation is shown in the following figure.

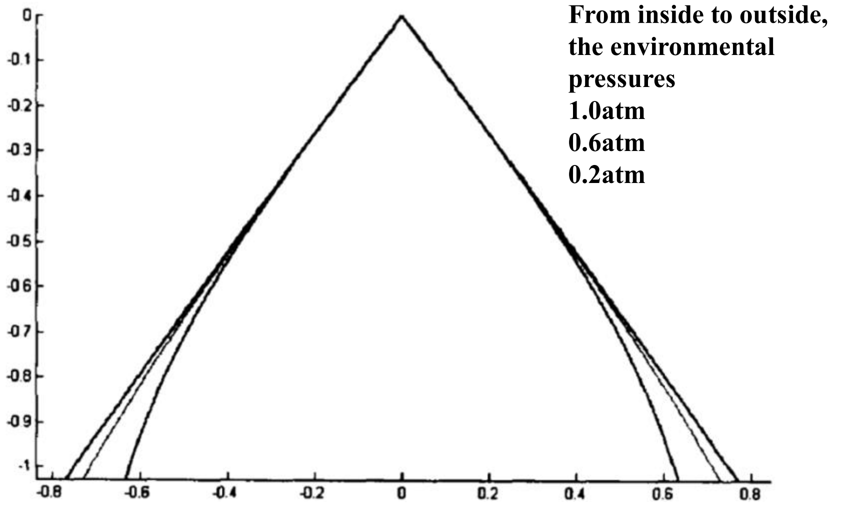

Figure 1. The trajectory of the droplets on the fog cone surface when the working air pressure is 0.6Mpa

3) In summary and domestic and foreign research shows that high-pressure spray dust reduction has a small diameter of fog particles, high speed of fog particle movement, fog particle density and fog particle range, small water consumption, large coverage area and nozzle is not easy to block and other significant advantages, the smaller the size of the water mist particle size the higher the dust reduction efficiency, but different particle sizes of dust particles correspond to a better water mist particle size; when using pressure-type atomization nozzle sink floating, dust reduction efficiency mainly depends on the water supply pressure, different particle sizes of dust require different water supply pressure (Ma, S.-P., & Kou, Z.-M., 2005). The normal atmospheric pressure in the Lhasa area is around 652.0 hPa, and the existing spray dust reduction equipment has larger atomized particles compared with that in the mainland, which affects the dust reduction efficiency of the equipment, so changing the pressure (dust reduction strength) of the water from the spray dust reduction equipment can well meet the requirements of efficient dust reduction, especially for fine dust, high-pressure spray dust reduction has a high dust reduction efficiency. In addition, the fog particles of high-pressure spray also have a certain electrostatic charge, which makes it a good purification effect for the fine dust that is difficult to purify due to the electrostatic phase absorption of dust.

2.3 Improvement of Existing Equipment

In response to the problems identified in the previous analysis and related research, the author improved the current spray dust reduction equipment in China and Lhasa construction health standards and dust pollution prevention requirements. The improved spray dust reduction equipment is shown in Figure 2, Figure 3, Figure 4 and Figure 5.

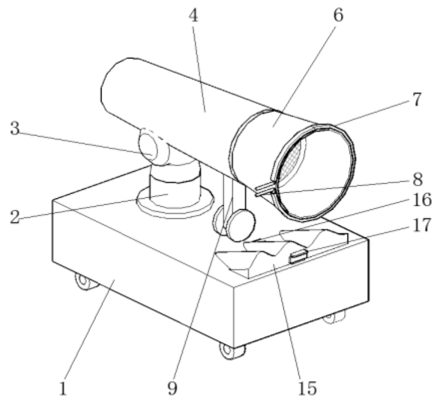

Figure 2. Schematic diagram of the overall orthographic structure

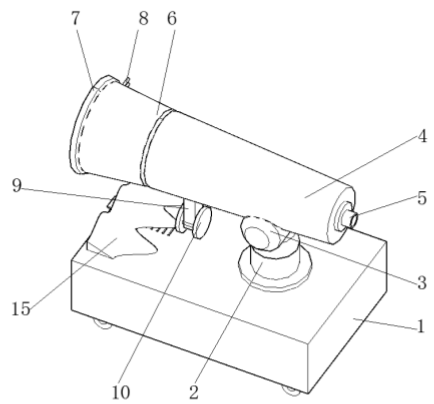

Figure 3. Schematic diagram of the overall side view surface structure

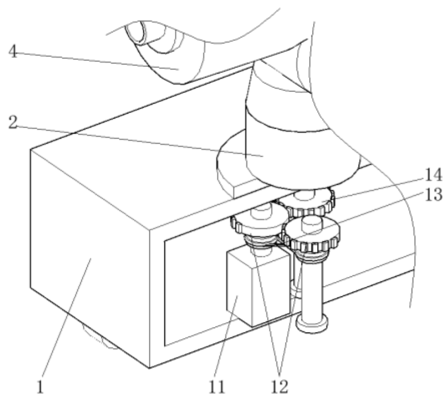

Figure 4. Schematic diagram of the internal structure of the main body

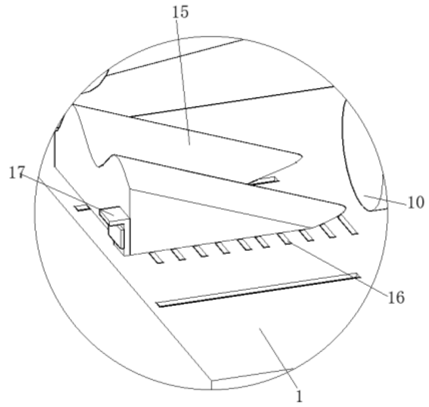

Figure 5. Schematic diagram of the connection structure between the adjustment plate and the main body of the device

(1, device body; 2, rotation column; 3, rotation axis; 4, atomizer; 5, water inlet; 6, waterproof adjustment cloth; 7, adjustment belt; 8, adjustment rope; 9, support rod; 10, roller; 11, adjustment motor; 12, adjustment gear; 13, belt; 14, linkage gear; 15, adjustment plate; 16, slot; 17, limit plate)

2.4 Working Principle

According to Figures 1-4, when the road construction dust reduction device is needed to reduce dust on the road construction site, first install the dust reduction device at the construction site, then inject water into the atomizer 4 through the water inlet 5, then the atomizer 4 will transform the water into water mist spray, the sprayed water mist will be able to adsorb the dust in the air to achieve the role of dust reduction, in the water mist spray, the staff can pull the adjustment rope 8 inside the adjustment belt 7. The staff can pull the adjusting rope 8 inside the adjusting belt 7, and the opening size of the waterproof adjusting cloth 6 will be smaller by the adjusting rope 8, and the water supply pressure can be changed under the adjusting effect of the opening size of the waterproof adjusting cloth 6, so that the dust reduction strength of the dust reduction device can be adjusted to facilitate the dust reduction device to adapt to more construction environments, which is conducive to improving the use experience of the dust reduction device.

According to Figures 1-4, when the atomizer 4 is working to reduce dust, the staff starts the adjusting motor 11 to drive the adjusting gear 12 to rotate, and as the two half number teeth marks of the adjusting gear 12 can repeatedly engage and rotate with the linkage gear 14 through the belt 13, so that the rotation column 2 above the linkage gear 14 can drive the atomizer 4 to swing left and right repeatedly, and then the staff pushes the "~"-shaped structure of the adjustment plate 15 set in the device above the main body 1 sliding, at this time the support rod 9 below the atomizer 4 will be through the roller 10 in the adjustment plate 15 above the rolling, drive the atomizer 4 up and down rotation swing, in the atomizer 4 multi-angle rotation role, so that the road construction with dust reduction device dust reduction effect and dust reduction range is greater, so that the dust reduction The device is more practical, and the position of the adjusting plate 15 can be fixed by the clamping of the slot 16 and the limit plate 17.

2.5 Comparison with Existing Equipment

Compared with the prior art, the beneficial effects of the present improved spraying and dust reduction equipment are.

(1) Through the linkage structure formed by the adjusting gear and the rotating column, the atomizer can be driven to swing repeatedly from left to right above the main body of the device under the action of the half tooth mark structure on the outside of the adjusting gear, thus making the dust reduction angle of this dust reduction device for road construction dust reduction operation larger, which is conducive to improving the practicality of such spray dust reduction and dust reduction device.

(2) Through the waterproof adjusting cloth attached to one end of the atomizer, the size of the waterproof adjusting cloth can be adjusted under the action of the adjusting rope on the outside of the waterproof adjusting cloth to make the size of the waterproof adjusting cloth adjustable, so as to adjust the dust reduction strength of the dust reduction device for road construction dust reduction operation and make the atomized particles smaller, making up for the problem of larger atomized particles when the device is used in highland areas, which is

conducive to improving the experience of using the dust reduction device.

(3) While improving the dust reduction efficiency, it also reduces the cost required for dust reduction operations in road construction.

3. Conclusion

By combining the characteristics of strong wind, high wind speed and changing wind direction in Lhasa, we analyze the deficiencies of the existing dust reduction equipment such as the lack of a wide range of dust reduction angles and the inability to adjust the dust reduction intensity, and we know from the analysis and investigation data that, with the increase of the spray supply pressure, the air atomization spray atomization particle size decreases, and the spray atomization flow rate also decreases; with the increase of the spray supply pressure, the air atomization The dust reduction efficiency of all-dust and respirable dust of the spray keeps increasing, but after exceeding the air pressure, the dust removal efficiency starts to decrease (Qian, J., 2017).

In this paper, we combine the above problems to add a linkage structure consisting of gears and rotating columns to the existing spray dust reduction equipment and a waterproof adjustable cloth that can be gathered, so that the equipment can swing repeatedly from left to right and the dust reduction intensity can be adjusted, thus enabling such equipment to cope with winds of different directions and strengths in the Tibetan plateau region, and under the typical region of Lhasa, the dust reduction intensity can be changed to compensate for the force majeure due to the lack of air pressure in the plateau and other It can make up for the problem of large atomized particles caused by the lack of pressure on the plateau, and make it better for road construction dust reduction in the Qinghai-Tibet Plateau region. Effectively alleviate the damage brought by road construction to the ecology around the road on the Tibetan plateau and the impact on the residents around the city road.

Fund Project

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