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Refined Dust Fine Control Method of Bulk Cargo Yard Based on Whole-field Monitoring

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Abstract. The fine dust control method and control system of bulk cargo yard based on whole-site monitoring are realized through the following paths. Firstly, the extinction coefficient of the whole area of the storage yard is obtained by using lidar, and the proportion relationship between the extinction coefficient and the dust concentration data measured at the same position is obtained to obtain the dust concentration distribution in the whole area. Secondly, the radar scanning plane is divided into N grids with the control range of each spray head as a grid unit, and the average dust concentration in each grid is calculated. Thirdly, the critical value of the average dust concentration and the critical value of dust contribution rate are set to judge the grid that needs to start the sprinkler head. Repeat the above process to achieve continuous fine control of dust in bulk cargo yard. The system not only improves the efficiency of dust suppression, but also reduces the amount of sprayed water, achieves the purpose of improving the efficiency of environmental protection effects, reducing the labor intensity of workers, and maximizing the utilization of water resources while effectively removing dust.

1. Introduction

A lot of research work has been carried out on the dust control of the storage yard at home and abroad. The "Operation Method of Intelligent Watering Decision System for Coal Yards" developed by Shitao Peng et al. uses monitoring of meteorological parameters and coal moisture content to determine reasonable watering for coal yards[1]. "A kind of real-time dust detection and intelligent sprinkler dust suppression device and method based on video technology" invented by Huang Zhen et al. is to record the real-time video data of yard dust by video monitoring device, calibrate it in combination with wind speed and wind direction, and finally determine the dust area and coordinates, so as to control the spraying device to spray water and reduce dust in different areas[2]. "A kind of environmental protection monitoring and pre control system for sprinkling and dust reduction" invented by Mr. Hou and others is to determine the dust area of the yard by combining the dust concentration monitoring device installed at the four corners of the yard boundary and controlling whether the sprinkler equipment sprinkles water.

However, whether it is through coal moisture content monitoring or video data monitoring, it is determined by indirect monitoring parameters whether sprinkling control is necessary, rather than using the intuitive data of dust concentration as the basis for judgment. The existing method of judging the dust-generating area by dust concentration cannot reflect the temporal and spatial distribution of dust in the yard boundary in real time because the monitoring equipment is installed at the boundary of the yard, so its control cannot achieve intelligent and accurate effects[3]. Therefore, an intelligent dust



control method for the entire storage yard that determines whether to issue sprinkling control commands based on the temporal and spatial distribution of dust concentrations in the entire storage yard is very necessary.

2. System operation method

2.1. "1+N" Port Dust Monitoring Program

"1 + n" scheme refers to one set of lidar dust pollutant monitoring equipment and N sets of on-line monitoring equipment for atmospheric environment in the field / field boundary. One set of lidar equipment obtains the concentration distribution information of pollutants at different heights by generating scattered light after the laser interacts with particles and gaseous molecules, and then uses N sets of on-line atmospheric environment equipment distributed in the field for concentration calibration[4] The scanning effect of lidar is shown in Figure 1.

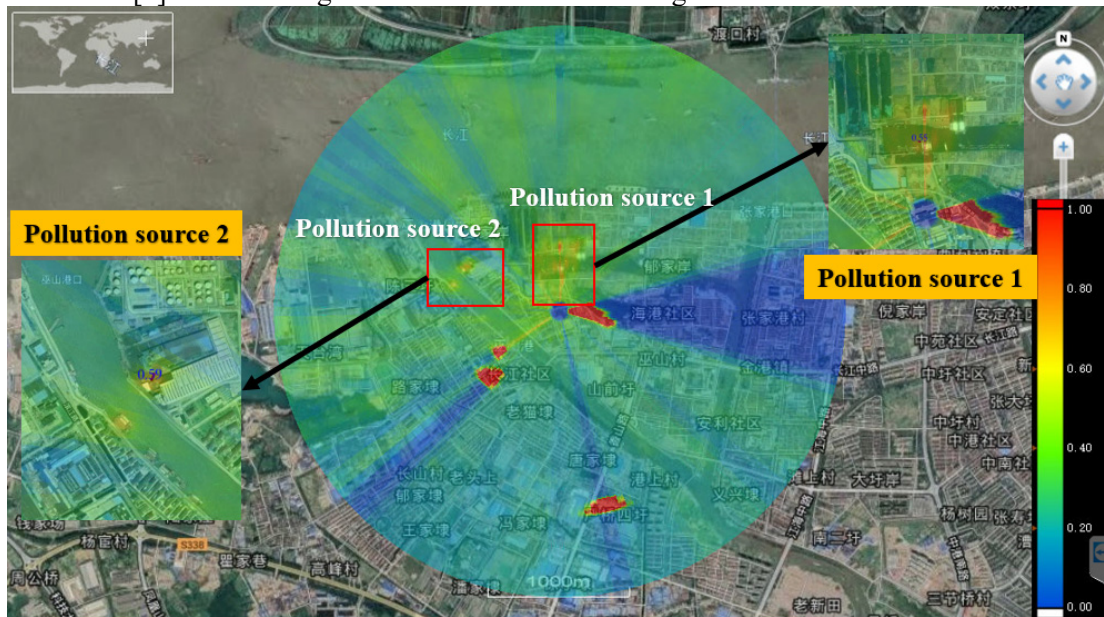


Figure 1. The scanning effect of lidar

Use the lidar installed at the height of H to scan the entire area of the yard horizontally to obtain the extinction coefficient E evenly distributed at N points in the yard.

$$E = \{E_1, E_2, \dots, E_i, \dots, E_N\} \quad (1)$$

At the same time, multiple dust online monitors uniformly installed in the yard are used to obtain dust concentration data at M points in the yard. The mass concentration P of TSP/PM₁₀/PM_{2.5}.

$$P = \{P_1, P_2, \dots, P_i, \dots, P_M\} \quad (2)$$

$$N \gg M \quad (3)$$

By comparing the dust concentration data P_i at the same position with the extinction coefficient E_i of the lidar at that point, the proportional relationship k between P_i and E_i is obtained, and the product of k and E is calculated to obtain the full range of dust concentration on a plane with a height of H Temporal and spatial distribution.

$$A = k \times P = \{kE_1, kE_2, \dots, kE_i, \dots, kE_N\} \quad (4)$$

2.2. Calculation method of dust emission contribution rate

Install a sprinkler system in the yard so that the sprinklers in the sprinkler system are evenly distributed in the yard, and according to the principle that the control range of each sprinkler head is

used as a grid unit, the plane with height H is divided N grids. Calculate the average dust concentration C of each grid based on the mass concentration of dust concentration data (TSP, PM_{10} or $PM_{2.5}$) at several points in each grid.

$$C = \{C_1, C_2, \dots, C_j, \dots, C_N\} \quad (5)$$

Set the critical value of average dust concentration P_0 and the critical value of contribution rate of dust emission T_0 , and judge whether the average dust concentration of each grid reaches the threshold for starting the sprinkler in the corresponding grid to spray water. When the average dust concentration C_j of each grid does not exceed the critical value P_0 of average dust concentration, the sprinkler in the grid will not be activated. When the average dust concentration C_j of any grid exceeds the critical value of average dust concentration P_0 , the grid contribution rate calculation is started.

According to formula (6), the contribution rate T_j of each grid is calculated.

$$T_j = \frac{Q_j}{Q_1 + Q_2 + \dots + Q_n} \times 100\% \quad (6)$$

In formula (6), Q is the amount of dust in a single grid, The dust emission in each grid is obtained by solving equations (7).

$$\begin{aligned} C_1 &= K_{11}Q_1 + K_{12}Q_2 + \dots + K_{1N}Q_N \\ C_2 &= K_{21}Q_1 + K_{22}Q_2 + \dots + K_{2N}Q_N \\ &\dots \dots \\ C_j &= K_{j1}Q_1 + K_{j2}Q_2 + \dots + K_{jN}Q_N \\ &\dots \dots \\ C_N &= K_{N1}Q_1 + K_{N2}Q_2 + \dots + K_{NN}Q_N \end{aligned} \quad (7)$$

In equation group (7), K is the dust concentration coefficient. The calculation method is formula (8).

$$K = \frac{1+\alpha_i}{2\pi u \sigma_y \sigma_z} \exp\left(-\frac{y^2}{2\sigma_y^2}\right) \exp\left[-\frac{(H)^2}{2\sigma_z^2}\right] \quad (8)$$

Among them, α is the ground reflection coefficient of dust, u is the average wind speed of storage yard, h is the height of lidar, σ_y is the diffusion coefficient of dust in the horizontal direction, σ_z is the diffusion coefficient of dust in the vertical direction, and Y is the vertical distance of the average wind direction axis on the two grid centers on the horizontal plane.

When the dust emission contribution rate T_j of each grid does not exceed the dust emission contribution rate critical value T_0 , the sprinkler in the grid will not be activated. When the dust emission contribution rate T_j of any grid exceeds the dust emission contribution rate critical value T_0 , the sprinklers in the corresponding grid that exceed the dust emission contribution rate critical value T_0 will be activated to perform operations on the grid area.

According to the preset interval time T , the above process is continuously repeated to achieve continuous and refined control of the bulk cargo yard dust.

3. Implementation cases

Use the yard dust fine control system to finely control the yard dust in a port bulk cargo yard. As shown in Figure 2, install a yard dust fine control system in a port bulk cargo yard to realize the yard grid layout of the bulk cargo yard dust fine control method. In the figure, the symbol " \circ " represents lidar, the symbol " \square " represents the dust online monitor, the symbol " \times " represents the sprinkler head of the sprinkler system, and the symbol " \otimes " represents the meteorological parameter meter.

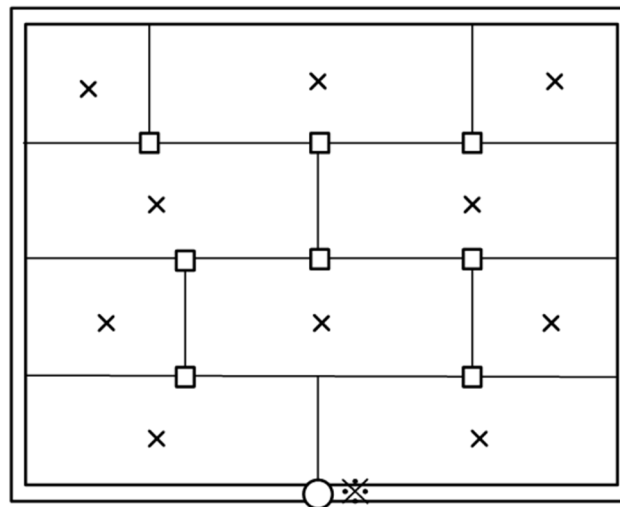


Figure 2. Schematic diagram of grid layout of storage yard

In this case, the lidar is installed at the boundary of the bulk cargo terminal and the installation height is 42m, the scanning period is 0.5h, the accuracy is 2° , and the range is 180° . The number of installed dust online monitors is 8, which are evenly distributed at sensitive points in the yard, and the installation height is 39m. The meteorological parameter meter is installed in the lidar neighbor measurement. The spray system includes 10 spray heads, evenly distributed in the yard.

The laser radar is used to scan the whole area of the storage yard, and the extinction coefficient e of 600 points in the yard is obtained. At the same time, the dust concentration data (PM10 mass concentration P) of 8 points in the yard were obtained by 8 dust on-line monitors which were evenly distributed. By comparing the dust concentration data P_i at the same position with the extinction coefficient E_i of lidar at that point, the proportional relationship K between P_i and E_i is obtained. Multiply k by E to get the global space-time distribution of dust concentration on a plane with a height of 42m.

According to the dust concentration data of several points in each grid, the average dust concentration of each grid is calculated: $C1=0.41$, $C2=0.37$, $C3=0.26$, $C4=0.19$, $C5=0.64$, $C6=0.66$, $C7=0.22$, $C8=0.38$, $C9=0.25$, $C10=0.12$.

Setting $P0=0.40$ and $t0=25\%$, the processor can judge whether the average dust concentration of each grid reaches the critical value of starting the spray head in the corresponding grid. In the average dust concentration calculation results of 10 grids, $C1 > 0.40$, $C5 > 0.40$, $C6 > 0.40$, so it is necessary to further calculate the contribution rate t of dust emission of each grid.

According to formula (6), calculate and solve equations (7), The results show that: $T1 = 3\%$, $T2 = 30\%$, $T3 = 5\%$, $T4 = 7\%$, $T5 = 10\%$, $T6 = 32\%$, $T7 = 3\%$, $T8 = 5\%$, $T9 = 3\%$, $T10 = 2\%$.

In the calculation results of the dust emission contribution rate of 10 grids, $T2 > 25\%$, $T6 > 25\%$, therefore, the processor outputs the sprinkling instruction to the sprinkler system control pump, and the control pump starts the sprinkler heads in the grid number 2 and the sprinkler heads in the grid number 6 to spray the area in the grid.

4. Concluding remarks

The purpose of this technology is to provide a fine dust control method for bulk cargo yards based on full-field monitoring that solves the problem of low dust control accuracy in traditional technologies. The system accurately finds each dust-generating material pile through intelligent inversion, and immediately starts the material yard spraying device once it finds that the pollution exceeds the standard, and carries out source-directed dust suppression for the material pile with high dust contribution rate.

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