Self-induction Dust Removal System Design at Construction Site Based on the Charged Spray

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Abstract. Most of current dust removal devices at construction site conduct the dust removal manually by coordinating the large-scale tools, and have low dust removal efficiency and small scope, with lower automation degree. For that reason, such paper designs a kind of self-induction dust removal system at construction site based on the charged spray. Such system includes the dust detection module, bus control module and electric spray device to guarantee the accuracy and timeliness for dust removal. Through experimental comparison and analysis, such system could improve the dust removal efficiency at construction site to some extent.

Keywords: Dust removal at construction site; Charged spray; Dust detection; Bus control

1. Introduction
With the rapid development of national economy and national attention on environmental problems, the technical transformation at lots of construction sites in current cities and towns to reduce the dissipation degree of fugitive dust has become a key task in the environmental protection. At present, as the mainstream for dust removal at construction site, the dust removal with water mist is characterized by large coverage area and convenient installation. The dust removal technology with water mist is widely applied in the construction environment at home and abroad, mainly including the dust removal technology by water spray, dust suppression technology with dry fog, and high-pressure spray dust removal technology [1], however, most of construction units focus on the manual control, and manually open and close the dust removal facility according to the concentration of fugitive dust. With regard to the result of dust removal with water mist, Chen Xi, et al. [2] design the high-pressure spray and dust fall device, and optimize the spray parameter through the numerical simulation, but the dust removal system has lower automation level; Hu Weiwei, et al. [3] design the purification device of charged spray air and improve the air purification efficiency by improving the runner design.

Based on the example of the T1 and T2 demonstration line project of modern tram in East Lake High-Tech Development Zone of Wuhan Municipal Construction Group, the paper designs the self-induction dust removal system at construction site based on the charged spray and adopts the AT89C52 single-chip processor and PC end as the controller. Such system could achieve: Real-time detection of fugitive dust concentration on the construction site; When the fugitive dust concentration reaches to certain value, automatically adjust the hydraulic pressure and the electric voltage to form the even charged fog drop,
thus effectively settling the dust particles at the construction site; When the concentration of fugitive dust reduces to certain value, the work stops.

2. Overall Composition of Dust Removal System

In order to improve the dust removal efficiency and automation degree at the construction site, the dust removal system designed in the paper owns the following functions: (1) Conduct the real-time detection to the fugitive dust concentration at the construction site and send the concentration to PC end; (2) Apply the high voltage in the annular electrode in the external of nozzle to have the fog drop charged and to improve the efficiency for the fog drop to absorb the particle of fugitive dust; (3) When the concentration of fugitive dust is lower than the set threshold value, the spray dust removal work ends. The dust removal system has the following structure principle and design:

2.1. Structure Principle of Dust Removal System

The dust removal system design at such construction site consists of several units, and each unit is composed of the dust detection device, electric spray device and bus control system at site. The workflow of unit is as follows: The dust detection device conducts the real-time detection to the fugitive dust concentration at construction site and sends to PC end. When the concentration value of fugitive dust is more than the set value, PC end controls the opening of the electrostatic generator and solenoid valve. The electrostatic generator generates the high pressure at the annular electrode, the solenoid valve is opened, then the high-pressure water column is subdivided under the electric charge effect and forms the conical charged spray. When the high-speed charged droplets meet with the particles of fugitive dust, the impact generates and the surrounding dust is absorbed, then the large-particle water grain group is coagulated, reaching very good dust removal effect. When the concentration of fugitive dust is reduced below the set value, the PC controls the closing of electrostatic generator and solenoid valve, then the spray dust removal ends. The schematic diagram of system structure is shown in Figure 1:

![Figure 1. Schematic Diagram of System Structure](image)

2.2. Structural Design of Dust Removal System

The system adopts the modular design, mainly including the dust detection module, control module and electric spray module. The schematic diagram of concrete structure of system is shown in Figure 2.
Figure 2. Schematic Diagram of System Structure

(1) Dust detection module
The dust detection module consists of the light emitter-LED lamp, light receiver- optotransistor, Lens-emitter and acceptor, and heat supply device-up draught joule resistance. When the parallel monochromatic light has incidence on the tested particle field, it would be scattered and absorbed by the surrounding particles, and the light intensity would be decayed. The relative concentration of dust in the tested field is obtained based on the attenuation rate [4], and the concentration value is sent to the PC end through the CAN bus to achieve the efficient and accurate detection of dust concentration.

(2) Control module
The control module consists of the PC end, main single-chip processor, CAN bus and each separate single-chip processor. As the terminal, the PC end is connected to the main single-chip processor. The CAN bus is arranged along the baffle at the construction site and connects to each separate single-chip processor. The main single-chip processor connects to the bus and conducts the communication with each separate single-chip processor. When the PM2.5 and PM10 concentration received by main single-chip processor exceed certain value, the PC end shows the concentration exceeds the standard and sends the control signal to the separate single-chip processor of controlling the electrostatic generator and solenoid valve through the CAN bus, then open the spray. When the dust concentration is reduced to certain value after spray, the PC end control the closing of electrostatic generator and solenoid valve through CAN bus, then the spray ends.

(3) Electric spray module
The electric spray module mainly consists of the water tank, electrostatic generator, PVC pipe, standing valve, solenoid valve, nozzle, annular electrode and alarm apparatus. The water tank provides the pressure so that the water flow flows to the solenoid valve through the pipe and standing valve, then the solenoid valve is open under the action of control module. The water flow forms the mist after...
passing through the nozzle. The electrostatic generator generates the 10-20KV high voltage after being opened under the control module, and acts on the external surrounding electrode of nozzle to form the high-pressure electric field. The droplets are charged by induction after passing through the electric field, and act with the particles of fugitive dust to achieve the dust fall effect.

3. Design of Control Module
In order to improve the traditional dust removal system and improve the automation degree of dust removal, the paper deeply researches the system control module which could achieve the following functions:

   (1) The module could conduct the real-time detection to the concentration of fugitive dust at the construction site and show the PM2.5 and PM10 concentration data in the PC end dynamically;

   (2) Main single-chip processor judges according to the concentration data from the dust detector and controls the opening and closing of the solenoid valve and the electrostatic generator;

   (3) The staff could conduct the commissioning to the assistant software at the PC end through the serial port to manually control the opening and closing of certain component in the dust removal system;

   (4) Start up the alarm module several seconds before each spray.

3.1. Control Flow
The particle of fugitive dust at construction site enters the dust sensor box. The opt transistor receives the ray scattered through the lens and transforms it into the signal of impulse wave [5], then the impulse wave signal will be output as the voltage. The concentration signal of dust is sent to the PC end through the CAN bus for the data processing, and the transmission interval of signal is 3S, which could basically achieve the real-time monitoring of concentration of fugitive dust. The threshold values of concentration of fugitive dust when beginning and stopping spraying are 100ug/m3 and 50ug/m3, respectively. Such threshold value could be changed and set at the PC end according to the environment and demand. When the concentration of fugitive dust is more than threshold values of concentration of fugitive dust when beginning spraying, the main single-chip processor controls the separate single-chip processor, thus controlling the closing of the solenoid valve and electrostatic generator. Specific Control Flow Chart is shown in Figure 3.

![Figure 3. Control Flow Chart](image)
3.2. Information Acquisition Module
The core component of this module is dust detector, which is responsible for collecting the concentration of dust PM2.5 and PM10 on the construction site. The detection is accurate, real-time and adjustable. The working process of dust detector is shown as follows: The dust monitor is powered by the 5V power supply module of separate single-chip processor, and the startup command is sent to the dust monitor by the PC end serial port debugging assistant software, and the dust concentration threshold is set for the beginning and the end of the spray. Then it sends the instruction to read PM2.5 and PM10 test data at regular time, which makes the software interface displays the test data dynamically. When it stops working, shutdown instructions are sent through PC end and power supply is stopped.

3.3. Fieldbus Control System
Considering that there are more control elements (up to hundreds of units) in the control system, and the information of the control elements is transmitted more frequently, and amount of data transmission is large (the preliminary estimate can reach 100MB/s), it is obvious that the ordinary single-chip processor cannot deal with the huge amount of information quickly and give feedback to the system in time, so the fieldbus control is used in this paper. The fieldbus control system consists of the PC end, main single-chip processor, CAN bus and each separate single-chip processor. As the terminal, the PC end is connected to the main single-chip processor. The CAN bus is arranged along the baffle at the construction site and connects to each separate single-chip processor. The main single-chip processor connects to the bus and conducts the communication with each separate single-chip processor.

4. Experimental Verification
In order to detect the dust removal effect of this system, this paper takes the construction area of modern tram T1 and T2 demonstration line of East Lake High-Tech Development Zone of Wuhan Municipal Construction Group as an example and carries on the experimental comparison and analysis in the ordinary spray state and charged spray state, respectively.

4.1. Experimental Design
The experimental system consists of water pump, dust generator, dust detector, anemometer and dust removal system. The water pump is used to provide the pressure required for the water flow atomization, and the dust generator is used to generate and transport dust with uniform concentration. In the experiment, the fan in the dust generator produces 0.5m/s airflow, adds the dust in the airflow stable place, forms the uniform dust field, and the dust removal system and the dust outlet are opposite with distance of 2 meters. The dust detector is arranged at the dust outlet and the rear side of the dust removal system to measure the dust concentration before and after the dust removal. The hydraulic pressure of the water pump is 3.2Mpa. The water pressure at the nozzle is 3.0Mpa, the width of the single nozzle is about 3m and the distance between the adjacent nozzles is 2.2m. In order to compare the dust removal efficiency in different states, the following two conditions are given under certain dust concentration: Ordinary spray: the electrostatic generator does not provide the voltage. At this time, a droplet (50-60um) with a radiation angle of 90°-100° and a distance of 1.1m is formed at the nozzle; Charged spray: the electrostatic generator provides 20KV voltage. Under the action of electric field, a charged droplet (40-50um) with a radiation angle of 100°-110° and a distance of about 1.2m is formed at the nozzle. Finally, the dust concentration in the normal spray and the nuclear power spray state is measured by the detector, and the dust removal efficiency under the two conditions is compared.

4.2. Experimental Results and Analysis
When Time=0, the dust concentration exceeded the standard and began to spray. From Figure 4, it can be seen that in 0-1.5 minutes, PM10 concentration of dust in normal spray state decreased from 200 ug/m³ to 89 ug/m³, and in charged spray state, decreased from 200 ug/m³ to 56 ug/m³; In 1.5-3 minutes, PM10 concentration tended to be stable. In the ordinary spray state, PM10 concentration was stable at
77 ug/m³, and PM10 concentration in the charged spray state was stable at 36 ug/m³. Therefore, the dust removal efficiency of the dust removal system studied in this paper is high.

![Dust Removal Efficiency under the Two Conditions](image)

**Figure 4.** PM10 Concentration Changes

5. Conclusion
Compared with the traditional dust removal system, it can realize the following items: Real-time detection of dust concentration on the construction site; By using the charged spray technology, the droplet is induced to be charged to increase the probability of meeting with dust and improve the dust removal efficiency; By using PC control and fieldbus control technology, all components are effectively combined to improve the degree of dust removal automation. Therefore, the dust removal system has a high degree of application.

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