The design of the dust suppression system in sand sorting process

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Abstract. The sand separation process will produce a lot of dust, which will cause serious harm to the environment and personnel. Only by adopting a suitable dust removal system structure can the expected dust removal effect be obtained. In this experiment, two sets of dust suppression system, namely negative pressure dust suppression system and water mist dust suppression system, were designed and manufactured. The dust suppression effect was tested under the conditions of different air volume, air inlet hood distance and water pressure/water volume. The experimental results show that: (1). Compared with the water mist dust suppression system, the negative pressure dust suppression system has a better dust suppression effect. After the dust suppression system is turned on, the dust concentration measured within 0.2 meters around the sorting area does not exceed 6.9 mg/m^3; (2). The air inlet volume of the negative pressure dust suppression system is recommended to be 1000 m3/h~1300 m^3/h, and the distance between the air inlet hood and the dust initiation point is recommended to be no more than 2.5 cm. (3). The water mist dust suppression system can reduce the dust concentration to about 12mg/m^3, however, there are some problems, such as slow response of dust suppression system, mud attached to the conveyor belt and affecting the transmission. The results can provide reference for the detailed design of the dust removal system.

1. Introduction

Material sorting is an effective method for classifying mixed materials. During the sorting process, especially for sand and soil materials, a significant amount of dust is generated. This dust not only causes pollution to the working environment but also poses a serious health risk to workers, particularly the respirable dust particles with a diameter smaller than 5μm, which can remain suspended in the air for a long time without settling. Additionally, the dust generated from sand and soil materials usually contains free silica. Prolonged exposure to such an environment can lead to the inhalation of these particles into the lungs, causing occupational pneumoconiosis and fibrosis [1-8].

In recent years, China has made remarkable progress in dust control. Research institutes, enterprises, and universities have developed numerous dust control technologies that have been implemented in production practices. In addition to common methods such as wet operations and personal protective measures, six main approaches have been established for dust prevention and control, including ventilation dust removal, sealed dust control, spray dust reduction, dust suppressants, dust collectors, and curtain dust barriers [9-13]. However, most researchers have focused on the study of individual dust control techniques, while comprehensive dust control measures have received limited attention [14-18].

In addition, limitations in the research of dust handling in China are beginning to emerge. Firstly, dust control is a comprehensive process that requires studying the corresponding dust generation mechanism and implementing targeted dust removal technologies for each different dust source in the production process. Secondly, the current research on dust removal technologies mainly focuses on equipment development, while neglecting dust prevention measures for dust sources in the production process. As the processing capacity requirements increase and the degree of mechanization continues to improve, controlling dust pollution in the material sorting process has become increasingly complex [19-20]. Therefore, it is necessary to conduct in-depth research on the dust generation characteristics of the sorting system and dust control measures.

This experiment used sand with a specific particle size distribution as the sorting material, and designed and built a sorting system test bench along with the corresponding negative pressure and water mist dust control systems. The study investigated the effectiveness of two dust control measures under different induced draft volumes, induced draft hood distances, and water pressure/water flow conditions. This research provides experimental evidence for controlling dust pollution in material sorting processes.

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2. The dust suppression system in sand sorting process

To obtain the dust generation characteristics during the specific sand sorting process, we constructed a sorting test bench consisting of a screw feeder, linear vibrating screen, conveyor belt, and swinging hopper. The sand handling capacity of this system is 10t/h. The physical and schematic diagrams of the test bench are shown in Figure 1.

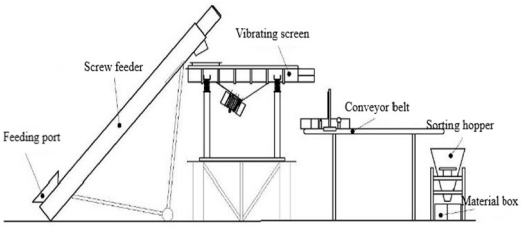


Fig. 1. The physical picture, structure picture and the distribution of dust concentration measuring points of the sorting system

The parameters of the major equipment used in the experiment are shown in Table 1.

Table. 1 Equipment type and technical parameter

Equipment Name	Main Technical Specifications
Spiral Feeder	Power: 4 kW, Processing Capacity: 10 t/h, Loading Height: 4mVibrating Screen
Vibrating Screen	Power: 2.2 kW, Processing Capacity: 10 t/h, Screen Apertures: 10 mm, 2 mm, 1 mm
Conveyor Belt	Power: 750W, Processing Capacity: 10 t/h, Conveyor Speed: 1 m/s, Dimensions: 2.5m × 0.5m
Dust Concentration Analyzer	Particle Size Range: 0-100μm, Measurement Range: 0-50 mg/m^3 Online Real-Time
Online Real-Time Monitoring System	Eight Channels, 4-20mA Signal Transmission Interface, Single-Channel Sampling Interval: 10s

The particle size distribution range and corresponding mass fractions of the specific sand tested in this experiment are shown in Table 2.

Table. 2 Particle size distribution of sandy soil

Particle Size Diameter (mm)	>20	10～20	1～10
Percentage (%)	4.5	27.06	34.98
Particle Size Diameter (mm)	0.42～1	0.074～0.42	<0.074
Percentage (%)	10.43	18.9	4.14

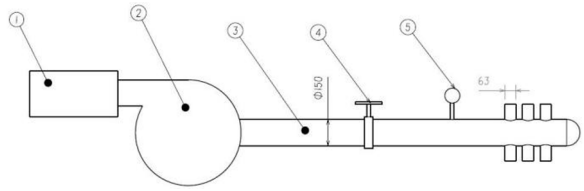
Particles with a diameter smaller than 10μm tend to remain suspended in the air for a long time. Table 3 shows the suspension velocities of particles of different diameters in the air. For particles with a diameter of about 100μm, their suspension velocity is approximately 0.79m/s, which is within the same order of magnitude as the sorting process and sorting speed in this project. However, once the particle diameter exceeds 100μm, the suspension velocity of the particles far exceeds the operating speed range of the test bench, and the particles will quickly settle after being suspended, as shown in the table below. Therefore, the main target for dust suppression in this project is particles with a diameter below 100μm, and the selected dust concentration sensor samples particles within the range of 0-100μm.

Table. 3 Dust suspension velocity

Particle Diameter Size（μm）	1	10	100	1000
Suspension velocity（m/s）	7.9e-5	7.9e-3	0.79	79

3 Negative pressure dust suppression system

The negative pressure dust suppression scheme adopted in this experiment is shown in figures 2, 3, and 4. After the dust suppression system is opened, the dust generated during the separation process enters the main pipe through the exhaust hood. The main pipe is equipped with a vortex flowmeter and flow control valve, which can obtain and control the air flow through the pipe in real time. A dust bag is installed at the outlet of the centrifugal induced draft fan, which can separate the inhaled dust from the air flow to avoid polluting the atmosphere and wasting materials. The power of the fan is 18.5kW, the air volume is 3000 m^3/h ~5000 m^3/h, and the total pressure is 9kPa.



1. Dust suppression cloth bag 2. Centrifugal fan 3. Centrifugal fan 4. Flow control valve 5. Flow meter

Fig. 2 The air inlet system of the negative pressure dust suppression system

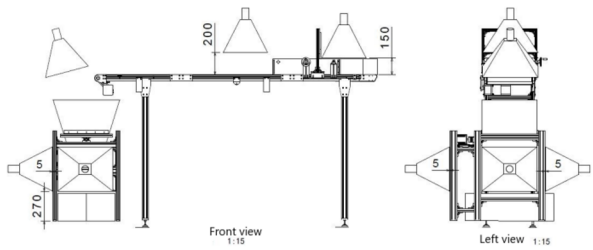


Fig. 3 The distribution and location of the air inlet hood

Fig. 4 Physical pictures of the negative pressure dust suppression system.

3.1 Experimental results of the negative pressure dust suppression scheme.

In order to obtain the optimal negative pressure dust suppression scheme, a comparison was made of the dust suppression effects of the negative pressure dust suppression system under seven different airflow conditions: 600 m^3/h, 700 m^3/h, 800 m^3/h, 900 m^3/h, 1000 m^3/h, 1300 m^3/h, and 1600 m^3/h. Additionally, the effects were evaluated under five different distances of the air induction hood: 0cm, 2.5 cm, 5 cm, 7.5 cm, and 10cm. Table 4 presents a comparison of dust concentrations before and after the operation of the negative pressure dust suppression system during the operation of the sorting system, with an air induction volume of 1000m^3/h.

Tab. 4 Comparison of average dust concentrations around the sorting system before and after the operation of the negative pressure dust suppression system (air induction volume of 1000m^3/h).

Unit : mg/m^3	Before negative pressure dust suppression	After negative pressure dust suppression
Point one	22.8	5.1
Point two	17.8	4.1
Point three	17	3.3
Point four	37.2	6.9

Point one:From the vibrating screen to the measuring point of the conveyor belt

Point two:Horizontal transportation measuring point of the conveyor belt;

Point three:the impact grading material funnel on the conveyor belt;

Point four:the impact grading material funnel on the conveyor belt

3.2 Dust suppression effectiveness testing at different air induction distances.

Figure 5 shows the variations in average dust concentration during the separation process for different distances between the air hood and the dust emission point. It can be observed that as the distance increases, the dust suppression effect gradually decreases. Specifically, when the distance exceeds 2.5cm, the dust suppression effect noticeably deteriorates. Based on these test results, it is recommended that the distance between the air hood and the dust emission point in the negative pressure dust suppression system should not exceed 2.5cm.

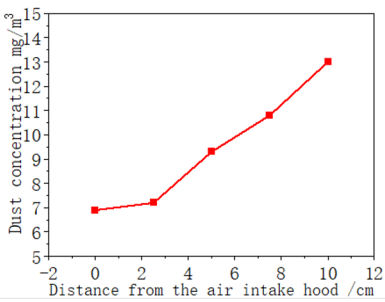


Fig. 5 The influence of the distance between the air inlet hood and the dust initiation point on dust suppression effect (air intake volume of 1000m^3/h).

3.3 Dust suppression effect test under different air intake volumes

Figure 6 shows the variations in average dust concentration during the separation process under seven different air intake volumes. It can be observed that as the air intake volume increases, the dust concentration decreases exponentially, as shown in equation (1).

$$Y = 4.69 + 103.8e^{-0.0039q} \quad (1)$$

Where, Y represents the dust emission amount from the sorting system, in mg/m^3; q represents the air intake volume of the negative pressure system, in m^3/h.

When the air intake increased from 600 m^3/h to 1600 m^3/h, the average dust concentration decreased from 14.5 mg/m^3 to 4.8 mg/m^3, a decrease of 66.9%. Taking into account the increase in power consumption and cost of the air blower, it is recommended that the air intake volume should be between 1000 m^3/h and 1300 m^3/h.

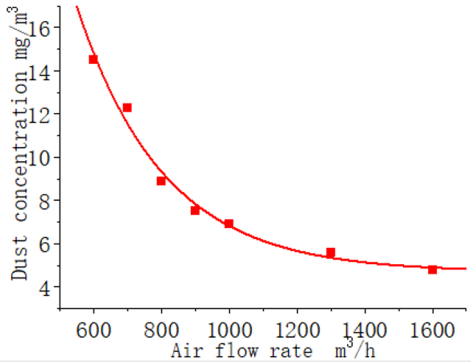


Fig. 6 The influence of the air inlet volume on dust suppression effect

4 Water mist dust suppression system

The water mist dust suppression scheme used in this experiment is shown in Figure 7. The pressurized pump pumps the water in the water tank into the pipeline, and obtains the water flow rate in real time through the flowmeter on the pipeline, and the atomized water volume is controlled by the diverter valve. A total of 9 atomizing nozzles are arranged on the pipeline, and the atomizing angle of each nozzle is adjustable from 0 to 33°, and the maximum water output of a single nozzle is 8L/h. The power of the booster pump is 300W. The maximum flow rate of the booster pump is 3000L/h. And the maximum head of the booster pump is 25m.

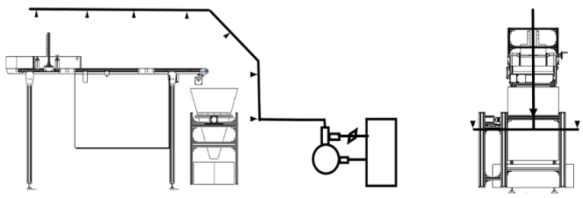


Fig. 7 The structure picture of the water mist dust suppression system

In order to obtain the dust suppression effect of the water mist dust suppression system under different spray water volume, the change rule of dust concentration during the separation process under the condition of 10L/h-50L/h water volume was tested and compared, as

shown in Figure 8. The dust concentration decreased linearly with the increase of spray water. However, compared with negative repressed dust, the dust concentration can be reduced by water mist dust suppression is limited. After the water mist dust suppression system is opened, the dust concentration around the sorting system can only be reduced from 16.1mg /m^3 when the spray water is 10L/h to 12mg/m^3 when the spray water is 50L/h, with a reduction of only about 25.5%. And there are several other problems in its use:

1. The on-site environment of water mist dust suppression is relatively harsh. After mixing with water mist, the sand turns into mud. If the water volume is too small, it cannot effectively suppress dust, as shown in Figure 9.

2. There is deviation in the mechanism of water mist dust suppression. Although water mist dust suppression can also reduce the dust concentration to 12mg/m^3, its mechanism is not to suppress dust after it rises, but to cause some sand and tiny particles to form mud and attach to the conveyor belt, greatly reducing the conveying efficiency of the belt and thereby reducing the dust concentration.

3. Compared with the fast response of the negative pressure dust suppression system, the response of the water mist dust suppression system is slow.

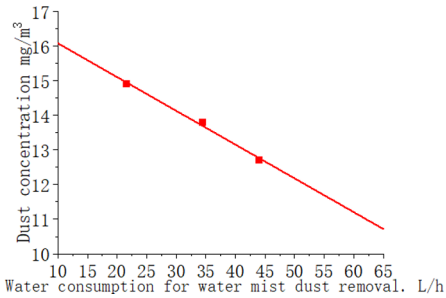


Fig. 8 The influence of the water volume on dust suppression effect

Fig. 9 After the water mist dust suppression system is turned on, pictures of the experiment site

5. Cost and reliability analysis

Cost and reliability are also important considerations in the design of dust removal systems. The overall cost includes three parts: (1) investment cost which is consist of the price of equipment and the installation costs; (2) operation cost which is consist of consumables replacement costs and maintenance costs during the use of the equipment; (3) The cost of energy consists of electricity and water. The average cost can be calculated according to formula (2).

$$C_a = \frac{C_i + C_o + C_e}{T} \tag{2}$$

Where, C_a represents the average cost; C_i represents the investment cost; C_o represents the operation cost; C_e represents the energy cost; T represents total hours worked.

Since this experiment uses an experimental device with temporary components, rather than a long-term operation device, it is difficult for us to obtain the accurate value of each cost. According to the small amount of data available, the power source of the water mist dust removal system is the booster pump, and its power only needs 300w. The power of the centrifugal fan in the negative pressure dust removal system needs 18.5kw, which is 62 times that of the booster pump. This means that the electricity cost of the negative pressure dust removal system is much higher than that of the water mist dust removal system.

Nevertheless, from experience, we still believe that the average cost of the two systems is comparable. There are three reasons for this:

1. Air is free, while water is paid for. In the case that the dust removal effect is equivalent to the negative pressure dust removal system, the water consumption of the water mist dust removal system exceeds 50L/h. The unit price of water is three to five times that of electricity in China.

2. Part of the soil will mix with water to form mud in the water mist dust removal system. These mud is easy to adhere to the conveyor belt or flow to the ground, resulting in equipment and environmental pollution. Frequent cleaning of equipment and sites comes with significant additional costs.

3. In addition, in order to obtain a good atomization effect in the water fog system, the outlet of the nozzle is very small, only 0.6mm, which is easy to be blocked. So the reliability of water mist system is not as good as that of negative pressure dust removal system. Removing a blockage or replacing a nozzle can be a major cost factor for maintenance.

Based on the above considerations, we still do not recommend the use of water mist dust removal systems in terms of cost effectiveness and reliability.

6. Conclusion and Prospect

6.1 Conclusion

The purpose of this experiment is to study the dust generated in the process of sand and stone separation, and to test the effect of dust suppression by designing and manufacturing two sets of dust suppression systems - negative suppression dust system and water mist dust suppression system. The experimental results show that the negative dust suppression system is significantly better than the water mist system in dust suppression effect, and can control the dust concentration around the

sorting area at a lower level. At the same time, the experiment also obtained some key operating parameters, such as the negative pressure system of the air intake is recommended to 1000m^3/h~1300m^3/h, the distance between the air intake hood and the dust point is not more than 2.5cm.

Although the investment cost of a water mist dust removal system may be lower, it has additional costs such as water costs, cleaning costs and maintenance costs. So that the average cost of the system may be comparable to that of a negative pressure dust removal system. Moreover, the reliability of the water mist dust removal system is lower, and it requires frequent cleaning and maintenance, which will increase the additional workload. This is also an important factor why we do not recommend the use of water mist dust removal systems.

6.2 Prospect

This experiment conducted systematic testing and analysis on the dust generation characteristics of the sand sorting system at each stage. The experimental results met the expected requirements. However, there are still some issues identified during the experiment that require further research and exploration.

1) Although this experiment has conducted a comparison of different dust suppression schemes for the sorting system, further optimization is needed for parameters such as negative pressure dust suppression scheme, structure and gas distribution ratio of the induced draft hood, and operation mode. In subsequent experiments, more combinations of experimental conditions should be added to simulate a wider range of actual conditions.

2) The dust concentration monitor used in this experiment had a sampling particle size range of 0~100μm, and the concentration value represented the sum of all dust sizes within this particle size range. It couldn't display the concentration of dust particles of different sizes in each stage separately, which limited its ability to accurately reveal the dust generation mechanism for different sand samples. Therefore, in the next stage, it is recommended to conduct in-depth research on the dust generation mechanism specific to different types of sand soils.

3) It needs long-term operational testing of the dust suppression system to assess its stability and durability.

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