Study on the Application of Tobacco Dust Purification System in Situ

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Abstract. Dust prevention and control in the tobacco industry has always been the top priority, because the discharge of tobacco dust can cause workers' pneumoconiosis, explosions, fires and other safety hazards. This article summarizes the advantages and disadvantages of the traditional three kinds of dust collectors. The author designed a tobacco dust in-situ purification system based on the principle of throttling gas-liquid exchange. The experiment selects the three factors of the initial liquid level, inlet wind speed, and feed concentration in the system, and conducts orthogonal experiments to obtain the purification efficiency of the system under different experimental conditions. The results show that the maximum purification efficiency of the laboratory can reach 99.27%. The purification efficiency is mainly referred to between 97%~99%. Through the actual application of the site, it can be known that under the long-term operation of the system, the emission concentration at different links and distances is still less than 2 mg/m³, which meets the national dust emission standard.

1. Foreword
In recent years, with the increasing awareness of environmental protection, tobacco enterprises began to attach great importance to dust prevention and control, and government environmental protection departments also strengthened the supervision of dust emission in the production process of enterprises. Tobacco dust can enter human lungs through nasal cavity, oral cavity and other respiratory tract [1], and its stimulation and sensitization on lung mucosa will cause chronic damage to human respiratory system, and even cause pulmonary fibrosis or pneumoconiosis [2-3]. At present, tobacco dust has gradually become one of the most serious occupational hazards in China. Therefore, tobacco dust has been listed in Classification Catalogue of Occupational Hazards (2015 Edition) issued by the state [4]. In addition, tobacco dust is flammable and explosive, and tobacco dust is also included as combustible dust in the Catalogue of Key Combustible Dust in Industry and Trade (2015 Edition) issued by the state. The research shows that tobacco dust in the suspended state with the concentration in the range of 10~68g/m³ may explode if it meets other explosion requirements [5]. If the waste gas containing tobacco dust is discharged into the atmosphere, it will cause dust and peculiar smell pollution to the surrounding air. This peculiar smell is pungent to a certain extent, and if the concentration is too high, it will cause nausea and vomiting [6-7]. According to GB 14554-1993 Emission Standards for Odor Pollutants, tobacco waste gas must be treated to meet the prescribed emission standards before it can be discharged to the outside world [8-9]. To sum up, tobacco processing enterprises must install dust removal system to control tobacco dust concentration as much as possible.

At present, most cigarette factories use cyclone dust collector, bag filter and wet dust collector (including wood film, wood bath and foam) to control tobacco dust [10]. The application of these
technologies has made remarkable achievements in controlling dust concentration, and the average dust concentration in the air has dropped from 50mg/m³ in the past to 10~20mg/m³ in the future. However, in the long-term practical application, the disadvantages of these technologies are gradually revealed [11]: the wet dust collector is completely denied because it is easy to cause blockage; Cyclone dust collector is only used in systems that emit a large amount of hot and humid gas individually; The efficiency of secondary dust removal by cyclone dust collector and bag filter is not significant. In order to ensure the dust removal effect, many tobacco companies have also introduced the dust removal system of Neodick Dust Removal Equipment Co., Ltd. from Germany. The dust removal equipment of this company is tailored to different types of dust removal systems for different enterprises. Its personalized design and super adsorption capacity effectively reduce the investment cost and ensure the working conditions of employees [12-13].

A large amount of dust will be produced in the production process of cigarette material loosening, switching, shredding, filter rod forming, etc., [14] and the dust production points are scattered. The dust control and treatment cannot be carried out efficiently by using the above-mentioned traditional dust removal mode of centralized treatment and discharging up to standard. At present, the traditional tobacco dust removal mode mainly has the following problems: (1) The dust control effect is poor: the air volume of dust control in some dust producing points is insufficient, and the dust overflow affects the dust control effect. The dust removal efficiency of the traditional dust removal mode is 80%~95% [15]. (2) High energy consumption: the production load of the traditional centralized dust removal mode is uneven, and no-load may occur at each dust removal point of the dust removal system, and the loss caused by such no-load accounts for about 28% [16-17] of the total dust removal energy consumption. (3) High material loss rate: due to unreasonable design of traditional dust control devices (such as belt conveyor head cover, etc.), a large number of qualified materials enter the dust remover, and the system material loss rate reaches 5% [18]. Based on these problems, based on the principle of throttling gas-liquid exchange, local purification, energy saving and stability, a typical belt transfer local purification system was built, and the field was evaluated, and good dust removal effect was achieved.

2. Introduction of on-Site Purification Mode
On-site purification is a new dust removal mode. Take belt transfer as an example. Figure 1 shows the composition and working process of on-site dust removal system. The local dust removal system is composed of dust control device, dust removal pipeline and throttling gas-liquid exchanger. Materials enter the dust control device through the nose cover, and the dust control device controls dust overflow and collects dust-containing gas, which is delivered to throttling gas-liquid exchanger through dust removal pipeline, and the tail gas is discharged locally after being purified by throttling gas-liquid exchanger. Local dust removal system can effectively solve the technical problems of traditional dust removal mode in cigarette factories, and its core features are: (1) Separate and nearby dust removal systems are set for each or several adjacent dust removal points, and the treated tail gas is discharged locally; (2) A soft connecting device is arranged at the belt transfer, which can buffer materials and reduce the loss caused by the impact between materials and belts.
3. Study on Adaptability of in-Situ Purification

3.1. Main Equipment
The core equipment of the on-site purification system is the throttle gas-liquid exchanger, and its hopper contains a certain height of dust removal liquid. After entering the throttle gas-liquid exchanger, the dusty gas flow will pass through the gap between the throttle plate and the dusty liquid level. At this time, due to the sharp decrease of the airflow channel and the sharp increase of the airflow speed, the airflow is throttled and a pressure difference is formed on both sides of the throttle plate. Under the action of this pressure difference, a strong impact is formed on the twisted liquid surface below the throttle plate, so that the airflow changes rapidly, and a part of liquid is peeled off from the liquid surface to form a water curtain, which traps and intercepts dust particles in the gas, separates the gas from the dust particles, and purifies the gas containing dust. Droplets containing dust particles are intercepted by the flow restriction plate and the dehydration plate, and return to the box hopper again; The purified clean gas is discharged from the air outlet to the gas-liquid exchanger. The principle of throttling exchange technology is shown in figure 2.

3.2. Experimental Material
Tobacco dust was selected as sample to test the total purification efficiency in laboratory. Before the experiment, the cut tobacco was dried in a constant temperature drying oven for 2.5 hours at 90℃. After drying, the cut tobacco was crushed by a crusher, and the dust was screened by a 120-mesh sampling sieve. The dust under the sieve was used in the experiment.
TES-1341 hot-wire anemometer (see figure 3(a)) is selected to measure the wind speed at the inlet and outlet of the dust collector. Choose self-made dust throwing device to throw dust; Choose Dusttrak dust concentration meter (see figure 3(b)) to measure the dust concentration at the inlet and outlet of dust remover; Collect the exhaust gas flow of scrubber at a sampling flow rate of 1m³/min, and directly measure the dust concentration after collecting for 12min. It is a desktop, battery-powered light scattering laser photometer with data recording function. The pump with external connection can provide a large number of real-time aerosol readings. It uses the sheath gas system to separate the aerosol in the optical element chamber, so that the optical element can be kept clean, which improves the reliability of the equipment and reduces the maintenance rate. It is suitable for clean office environment, harsh industrial production areas, buildings, environmental protection places and other outdoor applications.

![Figure 3. Experimental instrument.](image)

3.3. Experimental Design
Using the above-mentioned experimental instruments, an experimental platform was built, and the dust concentration before and after treatment was measured by a dust concentration meter to obtain the purification efficiency. The total amount of dust thrown was 60 mg/m³, 80 mg/m³ and 120 mg/m³. Through the total amount and speed of dust, the dust concentration and gas flow rate are calculated. The experimental principle is shown in figure 4.

![Figure 4. Experimental schematic diagram.](image)

Three factors, such as initial liquid level, inlet wind speed and feed concentration, were selected in the experiment to study the influence of these three factors on purification efficiency. 3 initial liquid levels, 2 wind speeds and 3 feeding concentrations are used for orthogonal design of 18 groups of tests, as shown in table 1. The purification efficiency of each group of experiments is tested and calculated respectively, and each group of tests is repeated 3 times to take the average value.
4. Analysis and Discussion

4.1. Adaptability of Dust Collector to Tobacco Dust

Throttling exchange belongs to forced gas-liquid countercurrent exchange, which includes shock exchange, centrifugal exchange and spray exchange. Gas-liquid contact is sufficient, liquid-gas relative movement speed is high, droplet size is small and exchange effect is good.

The total purification efficiency of throttle exchanger for tobacco dust is high, as shown in figure 5. In the experimental range, the purification efficiency is 94.62% at the lowest, and most of the purification efficiency is between 97% and 99%. The highest purification efficiency is 99.27% when the initial liquid level is 0mm, the inlet air speed is 6.5 m/s and the feed concentration is 120 mg/m³.

The purification efficiency of each wind speed and liquid level increased significantly with the increase of feed concentration, which increased rapidly at low concentration and slowed down at high concentration. The main reason is that with the increase of dust concentration, the contact probability between dust and catcher increases, which improves the collision probability of a single catcher to many dusts; However, with the further increase of concentration, the contact surface of the collector tends to be saturated, and the trapping energy increases and the region is relaxed.

![Figure 5. Purification efficiency of dust collector (0-6.5: initial liquid level 0 mm, inlet wind speed 6.5 m/s).](image)

According to the actual concentration of tobacco dust in the workshop, the appropriate liquid level and wind speed should be selected. Here, we select 6 groups of data 0-6.5, 0-8.5, 2-6.5, 2-8.5, 4-6.5 and 4-8.5 for comparison. According to table 2, when the feeding concentration is 60 mg/m³, the optimal initial liquid level is 0 mm and the inlet wind speed is 8.5 m/s; When the feed concentration is 120 mg/m³, the optimal initial liquid level is 0 mm and the inlet wind speed is 6.5 m/s; When the feed concentration is 180 mg/m³, the optimal initial liquid level is 2mm and the inlet air speed is 6.5 m/s.

| Factor                        | Level     |
|-------------------------------|-----------|
| Initial liquid level h₀(cm)   | 0, 2, 4   |
| Entrance wind speed (m/s)     | 6.5, 8.5  |
| Feeding concentration (mg/m³) | 60, 120, 180 |
Table 2. Data sheet of feed concentration, initial liquid level and inlet velocity.

| Feeding concentration /mg/m³ | (0-6.5)/% | (0-8.5)/% | (4-6.5)/% | (4-8.5)/% | (2-6.5)/% | (2-8.5)/% |
|-----------------------------|-----------|-----------|-----------|-----------|-----------|-----------|
| 60                          | 94.62     | 97.45     | 96.27     | 97.32     | 96.62     | 97.26     |
| 120                         | 99.27     | 98.31     | 98.85     | 98.65     | 98.92     | 98.05     |
| 180                         | 98.92     | 98.73     | 98.95     | 98.56     | 99.01     | 98.65     |

In addition, the dust used in the experiment was obtained by drying, crushing and sieving tobacco shreds. The actual particle size of tobacco dust is much larger than that used in the experiment, and higher removal efficiency can be achieved within the treatment capacity range. According to the relevant data of the last month, the emission limit of tobacco dust is 120mg/m³, so it is feasible to use throttle gas-liquid exchanger as the dust treatment terminal equipment of tobacco factory.

4.2. Field Evaluation of Dust Removal Efficiency

In the design of dust removal system, the relevant data of waste gas to be treated should be collected, including the data of waste gas flow rate, temperature, tobacco dust concentration, etc., to determine the treatment effect to be achieved, select the appropriate throttling exchanger, and then determine other structural parameters of the equipment according to relevant calculation and engineering experience. For example, in the dust removal system of a silk cutter in a workshop, two silk cutters are placed side by side, with the required air volume of 800m³/h and the dust concentration of 140mg/m³ (fluctuation range). The dedusting pipes of two shredders can be combined into one main pipe, and a gas-liquid exchanger is used to purify the gas and then discharge it locally. The system is shown in figure 6.

![Figure 6. On-site dust removal system of silk cutter in a workshop.](image)

Through the detection of dust in the workplace (see table 3), we found that the concentration of tobacco dust around the exhaust outlet of throttle gas-liquid exchanger was 0.5mg/m³, and the concentration of tobacco dust at the height of workers' breathing zone in the operation area was 1.0mg/m³. After 15 minutes of production, the tobacco dust concentration around the exhaust outlet of throttle gas-liquid exchanger is 0.7mg/m³, and the tobacco dust concentration at the height of workers' breathing zone in the operation area is 1.3mg/m³. After 75 minutes of production, the tobacco dust concentration around the exhaust outlet of throttle gas-liquid exchanger is 1.0mg/m³, and the tobacco dust concentration at the height of workers' breathing zone in the operation area is 1.5mg/m³.

According to the above analysis, the emission concentration of throttle gas-liquid exchanger in different links and distances is less than 2mg/m³, and the dust content of the treated gas meets the dust exposure limit in the air specified in GBZ2.1-2007 exposure limit of harmful occupational factors in the workplace, which can be discharged locally in the workshop.
Table 3. Dust detection results in workplace.

| Test item                                              | Detection position                          | Tobacco dust (mg/m³) | Standard value (mg/m³) | Evaluation of test results |
|--------------------------------------------------------|---------------------------------------------|----------------------|------------------------|----------------------------|
| Exhaust outlet left of exchanger (when not in production) |                                             | 0.5                  | ≤ 2                    | Qualified                  |
| Exhaust outlet right of exchanger (when not in production) |                                             | 0.5                  | ≤ 2                    | Qualified                  |
| Height of breathing zone of workers in operation area (when not in production) |                                             | 1.0                  | ≤ 2                    | Qualified                  |
| Exhaust outlet left of exchanger (production for 15 minutes) |                                             | 0.7                  | ≤ 2                    | Qualified                  |
| Exhaust outlet right of exchanger (15 minutes of production) |                                             | 0.7                  | ≤ 2                    | Qualified                  |
| Height of breathing zone of workers in operation area (15 minutes of production) |                                             | 1.3                  | ≤ 2                    | Qualified                  |
| Exhaust outlet left of exchanger (75 minutes of production) |                                             | 1.0                  | ≤ 2                    | Qualified                  |
| Exhaust outlet right of exchanger (75 minutes of production) |                                             | 1.0                  | ≤ 2                    | Qualified                  |
| Height of breathing zone of workers in operation area (75 minutes of production) |                                             | 1.5                  | ≤ 2                    | Qualified                  |

5. Conclusion
(1) The on-site purification system is suitable for tobacco dust purification, and the highest purification efficiency in laboratory can reach 99.27%, and most purification efficiencies are between 97% and 99%.
(2) In the long-term practical application, the emission concentration is less than 2mg/m³ at different links and distances, which reaches the minimum indoor and local standards.

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