Research on the Design Scheme of Explosive Dust Removal System and Piping

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Abstract: In the workplace where the material dust concentration is high and electric sparks are easy to generate, the dust is easy to explode. At this time, the design of the dust removal system and the piping layout plan are particularly important. This paper takes the design of dust removal system in a tobacco factory as an example. According to the working characteristics of the shredding and stem cutting equipment in the silk workshop, the corresponding wet dust removal device is designed in this kind of work environment. The structure of the dust removal system, process flow and piping design are given, Pressure loss calculation and fan selection, provide a reference for the design of dust removal systems in places that are prone to dust explosions.

1. Preface
In the industrial production process, the design of the dust removal link occupies an important position. First, a large amount of dust is generated in most industrial production links, and human inhalation of industrial dust will cause serious bodily harm; secondly, if the dust is directly discharged into the atmosphere without treatment, it will also cause air pollution around the factory. Therefore, in today's worldwide industrial production process, it is necessary to take the dust removal system into consideration in the design and construction of the link that generates dust in the production process.

The dust removal system commonly used in industry mainly includes bag type dust removal device, electric dust removal device, dry mechanical dust removal device and wet dust removal device. In some specific dust removal links, when the dust concentration reaches a certain concentration, it is easy to explode. At this time, most dust removal devices will not be able to use, such as the commonly used bag type dust removal and electric dust removal.

In this paper, the dust removal system and pipeline design is easy to produce sparks, and when the material dust reaches a certain concentration, it is easy to explode. The dust removal point of tobacco cutter in tobacco production belongs to this type. In the process of using the cutting machine, the knife grinding operation needs to be carried out continuously, and the knife grinding sparks will be produced in the process; moreover, the tobacco dust particles are small, and they will deflagration like flour in a certain concentration, so the wet dust removal device must be used in the dust removal process.

A kind of dust removal system and pipeline design scheme is studied, and the system research is carried out by the field investigation of a tobacco factory under a certain group.

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2. Design standards and requirements

2.1. Dust removal system of cutting machine in silk making workshop

Through on-site survey and surveying and mapping, determine the equipment model and formulate the engineering plan.

| Serial number | Name of dust removal system | model     | Dust properties                           | Treatment air volume (m³/h) |
|---------------|-----------------------------|-----------|------------------------------------------|-----------------------------|
| 1             | Dust removal system of leaf cutting machine | S2CH-18A-JS | Dust during cutting and sparks during grinding | 1800                        |
| 2             | Dust removal system of stalk cutting machine | S2CH-18A-JS | Dust during cutting and sparks during grinding | 1800                        |

2.2. Main contents and technical requirements

The dust removal system of the cutting machine provides all equipment, pipes (including supports and hangers) and auxiliary materials from the dust collection port of the cutting machine to the designated discharge port after dust gas treatment. At the same time, it includes the sewage pipe from the sewage outlet of the dust removal equipment to the designated sewage outlet. 304 stainless steel wire drawing plate is used for main equipment, 304 stainless steel wire drawing plate is used for pipeline, and food grade stainless steel pipe is used for stainless steel pipeline with diameter less than 160mm; national standard carbon steel material is used for equipment base and fan base.

The dust produced by the wire cutter is effectively collected (negative pressure wind) in the dust collector, and the sparks generated in the process of cutting and grinding are extinguished. The wet dust collector is adopted to achieve the effect of dust removal and spark extinguishment, and the sewage containing fine particle dust is discharged after filtration.

2.3. General design requirements

The mode of local discharge after treatment is adopted to save the site space and ensure the simplicity and beauty of the site. A set of on-site wet dust removal system is used for each production line's cutting machine, which can effectively extinguish the sparks generated by knife grinding while removing dust, and eliminate potential safety hazards. It is required that the equipment should be easy to maintain and operate stably for a long time.

2.3.1. System requirements

The design scheme and product manufacturing must meet the national quality standards, tobacco industry standards and the requirements of silk line process design. The noise level, dust concentration, dust emission concentration and noise emission of the equipment shall meet or exceed the requirements of relevant national standards.

2.3.2. Reliability

The system has the advantages of simple structure, high degree of automation, few moving parts, no wearing parts and high reliability in long-term operation.

2.3.3. Economy

Low total pressure loss, low energy consumption, low long-term operation and maintenance cost.

2.3.4. Process

The power fan of the system adopts frequency conversion control, which can adjust the air volume according to the actual needs, and set up flexible operation control mode. The dust removal pipeline is equipped with a wind balance device, so the wind pressure fluctuation is small when the system load changes, which meets the production requirements.
2.3.5. Safety
The main equipment has no moving parts, and there are few safety hazards. The various safety measures adopted in the dust removal system can ensure the safety of operators and equipment, and comply with the relevant national safety laws and regulations.

2.3.6. Treatment effect
It is required to meet the standards specified in the regulations, and can be directly discharged indoors, without the need to lead the treated gas to the outside. The dust emission concentration at the outlet of dedusting tail gas is $\leq 2 \text{mg/m}^3$.

3. Scheme optimization design

3.1. System overview
This design provides two sets of wet dust removal system for the wire cutting line, which is used to deal with the dust generated by two stem cutting machines and two leaf cutting machines, and the dust-containing waste gas generated by grinding wheel, and extinguish the sparks generated in the process of grinding, so as to eliminate the potential safety hazard and meet the process requirements of the wire cutting machine.

The scheme adopts wet dust collector and water washing method, with simple system structure, few moving parts, convenient maintenance, small equipment area, short air duct length and remarkable energy saving effect, meeting the requirements of field use.

Grinding wheel dust and tobacco dust with sparks will be produced when the cutter is working. The cutter usually has its own dust collection port to collect grinding wheel dust and tobacco dust, so it is necessary to purify the dust containing waste gas. The traditional purification method is to collect the waste gas of several cutting machines in the silk production line and transport it to the bag filter in the dust removal room for treatment. In practice, sparks will ignite the dust in the bag or pipe, which has certain potential safety hazards. In addition, the air volume required for the dust removal of the cutting machine is small, and the pipeline is generally long in the way of unified collection and treatment. A large amount of electric energy is consumed in the conveying process of the dust removal air, which is not conducive to energy saving and consumption reduction. Considering the above factors, two sets of wire cutters and two sets of stem cutters are separately equipped with local wet dust collectors, which can not only extinguish grinding wheel sparks, but also efficiently capture fine tobacco dust. The dust collector uses water as the dust removal medium, which has low water consumption. The sewage is directly discharged into the floor drain of the workshop after simple filtration. The dust removal equipment occupies a small area and can be placed flexibly. The dust removal equipment has no moving parts, low failure rate, high automation level and simple maintenance. The system design is advanced, scientific and practical.

3.2. System flow chart
The local dust removal system of cutting machine is composed of wet dust collector, dust removal pipeline, power fan, water inlet and drainage pipeline, etc. The process flow is shown in the figure below.

![Process flow chart of dust removal system of wire cutter](image)
3.3. Dust removal point and air volume

3.3.1 Dust removal system of leaf cutting machine

The dedusting system of leaf cutting machine includes the dedusting air of two leaf line cutting machines. The two cutting machines have the same model. The dedusting air is used to collect the sparks generated by the cutter grinding and the dust control of the dust collecting cover at the blanking port. According to the parameter data of the cutter, the air volume of a single dedusting machine is 700 m$^3$/h, and the pressure loss is about 300 Pa according to the on-site detection. Refer to the following table for specific data.

| Serial number | Dust removal point type | Air volume m$^3$/h | Pressure loss Pa |
|---------------|-------------------------|--------------------|-----------------|
| 1             | Leaf cutting machine 1   | Process dedusting  | 700             | 300             |
| 2             | Leaf cutting machine 2   | Process dedusting  | 700             | 300             |

The total air volume of the system is calculated according to the two cutting machines working at the same time, and the make-up air volume of the wind balance device is 400 m$^3$/h, so the total air volume of the system design $q = 1800$ m$^3$/h.

3.3.2. Dust removal system of stalk cutting machine

The dust removal system of stem line cutting machine includes the dust removal air of two stem line cutting machines. The two cutting machines have the same model. The dust removal air is used to collect the sparks generated by the cutter grinding and the dust control of the dust collecting cover at the blanking port. According to the parameter data of the cutting machine, the single dust removal air volume is 700 m$^3$/h. According to the previous field detection of the same machine, the pressure loss is about 300 Pa. Refer to the following table for specific data.

| Serial number | Dust removal point type | Air volume m$^3$/h | Pressure loss Pa |
|---------------|-------------------------|--------------------|-----------------|
| 1             | Stem cutting machine 1   | Process dedusting  | 700             | 300             |
| 2             | Stem cutting machine 2   | Process dedusting  | 700             | 300             |

The total air volume of the system is calculated according to the two cutting machines working at the same time, and the make-up air volume of the wind balance device is 400 m$^3$/h, so the total air volume of the system design $q = 1800$ m$^3$/h.

3.4. Piping system design

The pipe network layout of the dust removal system should fully consider the nature of the flue gas and dust at each dust removal point. The pipeline layout should be straight and concise, the length of the pipeline should be as short as possible, the air volume adjustment and control should be convenient and effective, and the wind speed design of the pipeline should be reasonable. According to the characteristics of tobacco dust, considering the requirements of energy saving, the pipe wind speed $V$ is designed as 13-20m/s. According to the above principles, draw the system diagram.
3.5. Calculation of system pressure loss

According to the system diagram, select 1-2-4-5-6-7-8 as the main pipe, and list the calculation table of wind pressure of each branch pipe and main pipe.

Table 4: Calculation table of pipeline wind pressure

| number | 1-2 | 2-4 | 3-4 | 4-5 | 6-7 | 7-8 | Main road |
|--------|-----|-----|-----|-----|-----|-----|-----------|
| Air volume Q (m³/h) | 700 | 1100 | 700 | 1800 | 1800 | 1800 | 1800 |
| Wind speed v (m/s) | 19 | 16 | 19 | 13.3 | 13.3 | 13.3 | -- |
| Pipe diameter D (mm) | 114 | 159 | 114 | 220 | 220 | -- | -- |
| Pipe length L (m) | 4 | 3.5 | 4 | 6 | 2.5 | -- | -- |
| Equivalent local resistance coefficient ξ | 0.64 | 0.385 | 0.64 | 0.42 | 0.175 | -- | -- |
| Local resistance coefficient ∑ξ | 1.02 | -0.3 | -0.08 | 0.56 | 0.38 | 1.75 | -- |
| Total resistance of pipe section ΔP (Pa) | 360 | 13 | 121 | 104 | 59 | 160 | 696 |

The total pipe resistance

\[ \Delta P = (\xi + \sum \xi) \times \rho v^2 / 2 \]  \hspace{1cm} (1)

Where \( \xi \) is the equivalent local resistance coefficient, which can be obtained by looking up the table, and \( \Sigma \xi \) is the sum of the local resistance coefficients. The dust removal air density \( \rho \) is taken as 20 °C atmospheric dry air density 1.205 kg/m³. The pressure loss of main pipeline is \( P_0 = 696 \) Pa.

The total pressure loss of system

\[ P_Z = P_0 + P_C + P_I \]  \hspace{1cm} (2)

Where \( P_C \) is the pressure loss of precipitator (including internal pipeline), \( P_C = 1200 \) Pa, and inlet pressure loss \( P_I = 300 \) Pa. Therefore, the total pressure loss of system \( P_Z = 2200 \) Pa.

3.6. Fan selection

According to the parameter requirements and referring to the fan samples, the fan parameters are selected as follows: air volume 2214 m³/h, total pressure 2905 Pa, speed 2900 r/min, power 3 kW.

4. Conclusion

To sum up, the design scheme describes a kind of dust removal system and pipeline design of flammable and explosive dust in detail, and the design content is close to the engineering practice, which is convenient for technical personnel of relevant directions to learn from.

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