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Self-cleaning condensation and electrostatic adsorption cutting oil mist purification device

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Abstract: *This device provides a solution to the problem that the electrostatic adsorption technology is not enough to treat cutting oil mist and the electrode plate is not cleaned in time, which leads to the reduction of treatment effect. When the mechanical processing plant is engaged in production activities, after the generated oil mist enters the air, the larger droplets in the oil mist are removed after being treated by the condensation device, and the residual fine oil mist is cooled and aggregated into larger droplets, which are adsorbed by the electrostatic device. At the same time, the device integrates the cleaning function to achieve the purpose of cleaning the electrode plate in time. This device can effectively reduce the discharge of oil mist and has a broad application prospect.*

Keywords: *condensation, electrostatic adsorption, cutting oil mist purification*

1. Introduction

Cutting fluid is widely used to lubricate, cool and clean tools and machined parts in machining manufacturing industry. In the process of machining, under the atomization caused by high-pressure jet, high-speed impact and evaporation caused by cutting heat, cutting fluid will produce a large number of industrial oil mist containing many toxic components, which will endanger the health of operators and seriously affect air quality [1].

The existing oil mist waste gas treatment devices include spray removal device, centrifugal separation device, electrostatic adsorption device and oil mist filter. Spray removal device is only suitable for scenes with low air quality requirements and low oil mist removal rate; The energy consumption of centrifugal separation device is high; The oil mist filter needs to change the filter element frequently, and the use cost is high; The comprehensive effect of electrostatic removal device is good, but the removal rate is not high when the concentration of oil mist in the air is high [2], and most of the oil and gas are flammable, which has potential safety hazards, and the process of cleaning the electrode plate is complicated, which consumes a lot of human resources and water resources. Therefore, in order to solve the problems of insufficient oil mist treatment and difficult cleaning of electrostatic adsorption device, a self-cleaning device for cutting oil mist based on condensation and electrostatic adsorption is designed.

2. Scheme design

2.1. Overall scheme design

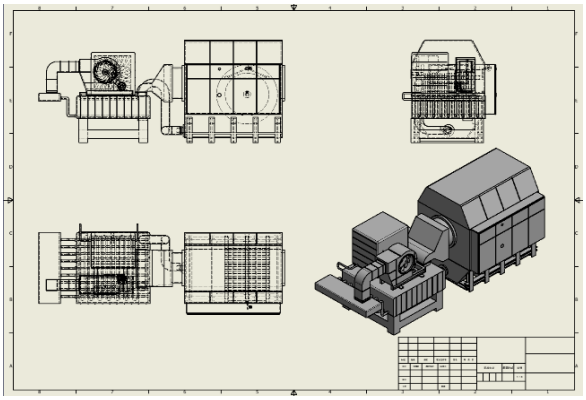

Figure 1: Device Engineering Drawing.

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The device consists of three modules, namely, condensation module, electrostatic adsorption module and automatic cleaning module, which are directly connected through gas pipelines to treat polluted air containing oil mist in stages, as shown in Figure 1.

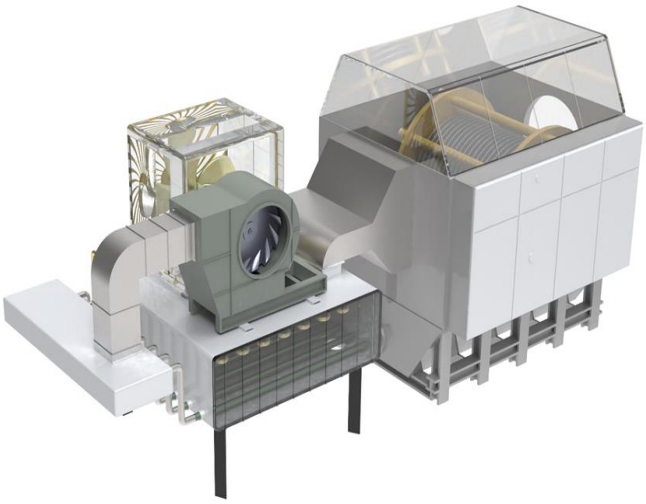

Figure 2: Integral device.

During operation, the motor is started first, so that the fan drives the fan blades to rotate through the shaft, and then the waste gas oil mist is sucked into the device. The sucked oil mist enters the condensation system through the porous conduit, fully contacts with cold water to realize condensation, forms large oil droplets, and then is discharged through the oil discharge hole. The remaining fine oil droplets that are not discharged enter the electrostatic adsorption module through the blower. Under the appropriate air humidity and voltage, the electrode plate ionizes the surrounding air [3], so that the incoming oil and gas are charged. When the oil on the electrode plate accumulates to a certain amount, the adsorption of the electrode plate will weaken, or even cause a short circuit [3], and then an automatic cleaning device is needed to deal with it. When the automatic cleaning device is running, hot water is sprayed from the double-layer porous water pipe at the top to soften the accumulated oil below, and then the electrode plate connecting shaft motor is started to make the shaft drive the electrode plate to rotate, so that the oil attached to it is thrown out to achieve the cleaning effect, as shown in Figure 2.

2.2. Condensation module

2.2.1. Condenser box device

Figure 3: Device diagram of condensation box.

Oil mist sucked by centrifugal fan will enter the porous conduit and then emerge from the hole. When cutting parts, the cutting oil is broken by the liquid due to the fierce impact of the liquid on the fixed and rotating units in the machine tool system, forming fine droplets floating in the working environment [4]. The oil mist produced in this case usually exists in the form of small droplets with a wide diameter range, usually 2 ~ 10 μ m. If this kind of oil drops enter the electrostatic field, it is easy to cause short circuit of the electrostatic field and the removal efficiency is low. The smaller oil mist bubbles generated through the small holes rise from the container filled with water, and when it meets the water with lower temperature, the oil mist condenses into larger oil droplets and stays in the water.

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Because the cutting oil is insoluble in water, and its density is less than that of water, it will float and gather on the water surface under the action of buoyancy, and when there is more accumulation, the cutting oil will flow out from the oil outlet. The pipe in the upper part of the water body in the figure 3 is a cooling pipe, which is connected with a condenser to cool the water body. The temperature difference after the water body is cooled makes the water convection, and the water with lower temperature flows downward, which is opposite to the direction of the oil mist, and the contact area between the water and the oil mist becomes larger, so that the oil mist can be condensed more fully. Oil and gas not removed by this device are removed by electrostatic adsorption device. This condensation device is equivalent to the pretreatment of oil mist, which makes the larger oil droplets be separated in advance, and at the same time reduces the overall concentration of oil and reduces the difficulty of subsequent separation.

2.3. Electrostatic adsorption module

2.3.1. Electrostatic adsorption device

When cutting parts, a large amount of heat is generated in the cutting area, which is transferred into the cutting fluid to make its temperature obviously higher than the saturation temperature, and it boils on the solid-liquid contact surface and produces steam. These vapors then condense with small droplets or other particles in the surrounding air as the core, forming oil mist [5]. The oil mist produced in this case is usually less than 2μm in particle size, which is difficult to remove in the first purification process.

After the polluted air goes through the first process, the oil mist of 2 ~ 10 μ m is removed, and the remaining oil mist that has not been removed enters the electrostatic adsorption device module. The electrostatic adsorption device is composed of a plurality of electrode plates and shells, and then high-voltage electricity is applied to the electrode plates, and the high-voltage electrode plates ionize the air, so that a large number of positive and negative particles are generated. When oil and gas float between a plurality of electric field plates, oil and gas molecules absorb a large number of positive and negative particles, thus moving to the electrode plates under the action of the electric field, and finally adhering to the electrode plates. When the oil reaches a certain amount, the accumulated oil will flow to the oil tank below the electrode plates under the action of gravity, and finally be stored in the oil tank, as shown in Figure 4.

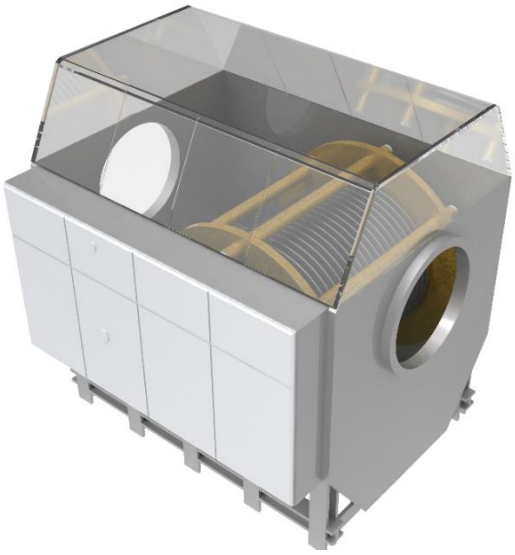

Figure 4: Overall diagram of electrostatic adsorption device.

2.4. Automatic cleaning module

2.4.1. Double-layer porous water pipe device

The double-layer porous water pipe device is divided into two layers, which are inserted and distributed on the shell of the electrostatic adsorption device and can be twitched. When the electrode plate stops running, start the water source switch to make the porous water pipe spray hot water. Although water and oil are immiscible, hot water can soften the oil [6] attached to the electrode plate, which is convenient to improve the oil throwing efficiency of the subsequent rotating device. When the rotation

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of the polar plate is finished, the softened oil is shaken off the polar plate, as shown in Figure 5.

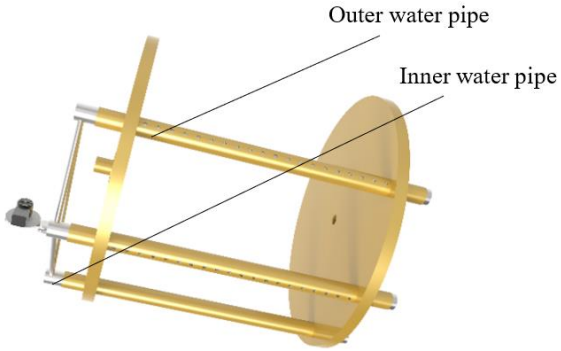

Figure 5: Porous water pipe

The opening and closing of the water pipes is realized by the motor, and the number of turns of the motor determines whether the small holes of the inner and outer water pipes overlap, so as to achieve the purpose of controlling the water flow.

2.4.2. Electrode plate coupling device

The electrode plates horizontally arranged in the electrostatic adsorption device are connected by connecting shafts made of insulating materials, and the connecting shafts of the electrode plates run through both ends of the shell of the whole electrostatic adsorption device. When hot water is sprayed from the double-layer porous water pipe, the outer layer of the water pipe is moved, so that each layer of water pipe can cover its own water outlet hole, so that oil can be prevented from entering the water pipe during subsequent oil throwing. After the outer layer of the water pipe is moved, the motor is started to make the connecting shaft rotate, and then the electrode plate connected to it rotates. During the rotation of the electrode plate, the cutting oil on the electrode plate is thrown out into the oil tank below due to high-speed rotation. In the past, the electrode plate was cleaned by high-pressure water gun and manual erasure [7]. However, the high-pressure water gun will waste water resources and easily deform the electrode plate [8], which will reduce the adsorption rate and shorten the service life. Manual erasure requires a lot of human resources, and the erasure speed is slow, and the process is cumbersome, time-consuming and labor-intensive , as shown in Figure 6.

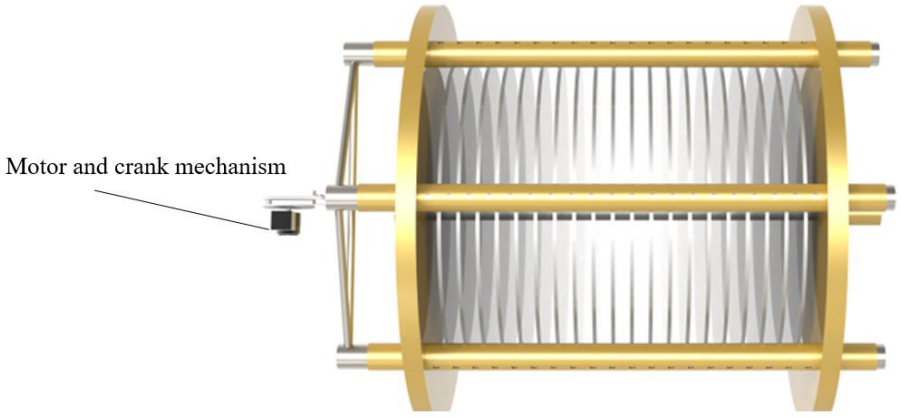

Figure 6: Coupling part.

3. Results

3.1 Feasibility analysis of comparison with traditional oil mist treatment device

Aiming at these problems, the device has made the following improvements: the condensing oil mist removal device can separate the oil mist with larger particles, and the electrostatic adsorption device can separate the oil mist with smaller particles; The electrostatic adsorption device is equipped with an automatic cleaning device, which has the advantages of simple cleaning mode and high degree of

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automation, and can be cleaned many times in a short period of time, thus solving the problem of less cleaning times due to the difficulty of cleaning mode, as shown in Table 1.

Table 1: Traditional Oil Fog Treatment.

Traditional oil mist treatment method	Disadvantages of traditional oil mist treatment methods
Mechanical separation method	The baffle screen is easy to break, which leads to the direct discharge of oil mist; Short maintenance cycle; The purification efficiency is not high
Water mist spraying method	Only suitable for the treatment of smaller oil droplets.
Electrostatic adsorption method	The absorption efficiency of the electrode plate becomes lower with time.
centrifugal separation	Only suitable for the treatment of larger oil droplets.

3.2 Feasibility Analysis of Removing Oil Fog by Condensing Device

When the centrifugal fan sucks the air containing oil mist into the porous duct, the air with oil mist floats upward with the bubbles generated by the small holes. When the oil mist comes into contact with cold water, it will gather into large oil droplets due to the condensation effect, and the density of the oil droplets is less than that of water, which will cause the oil droplets to move upward, and conversely, the upper water will move downward. The heat pipe, that is, the cooling part, is located on the upper layer of the water tank, making the upper water temperature lower. This process will make the water and oil droplets contact more fully, which is equivalent to a positive feedback effect for a certain period of time. Finally, the large oil droplets float on the water surface and then are discharged from the oil outlet.

3.3 Feasibility Analysis of Removing Oil Fog by Electrostatic Field

3.3.1 Effect of oil mist concentration on removal efficiency

Oil mist itself is an insulator and is not charged. After the first process, the oil mist enters the electrostatic field. Under the ionization of appropriate air humidity and appropriate voltage, the oil mist will have a certain amount of charge, and it will move to each electrode plate under the action of electric field. With the change of time, the concentration of oil mist will gradually increase, and the charged oil mist particles will increase, while the total space charge will remain unchanged at a fixed voltage, so the amount of gas charge will decrease, thus inhibiting the overall drive rate. In this device, the voltage applied to the charged electrode plate is about -14V, and the oil mist particle diameter after the first process is about 1.25μm. When the concentration of oil mist at the inlet is changed from 100mg/m3 to 300mg/m3, the collection efficiency of electrostatic precipitator for the oil mist particle diameter of 1.25μm is only reduced from 90.7% to 84.1%[3], while the accumulated concentration of oil mist on this electrode plate generally does not exceed 350 mg. Therefore, it is feasible to remove oil mist by electrostatic field in this device.

3.3.2 Feasibility analysis of oil mist humidity on removal efficiency

Because the blower blows out hot air, which is generally about 100℃, there are many condensed air flows into the electrostatic device and the cross-sectional area is small, so the humidity of the air flows into the device after contacting the hot air is not much changed compared with the humidity of the original oil. The humidity of oil is about 50% to 70%. According to the literature search, the collection efficiency of electrode plate is the highest under the air humidity of 60%, and within a certain range, the humidity increases [8], that is, the more moisture in the air flow, the lower the specific resistance of particles, and the charged particles move to the electrode plate to promote the release of charges; After the oil mist carries water molecules, the conductivity increases, and the breakdown voltage of the electrostatic device will also rise, so it can run at a higher working voltage. The interaction force between oil mist and between oil mist and electrode plate is increased, thus increasing the collection efficiency of oil mist [3].

3.4 Compared with the existing electrode plate cleaning technology

The existing electrode plate cleaning technology is mainly to clean the electrode plate with high-pressure water gun, but long-term cleaning with high-pressure water gun is easy to damage the electrode plate, such as deformation of the electrode plate. The existing cleaning cycle is generally 2 months, mainly to avoid the damage of the electrode plate caused by frequent disassembly and maintenance by manpower. However, the longer the cleaning cycle, the greater the possibility of electrode plate damage.

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Therefore, the automatic cleaning technology of this device can shorten the cleaning cycle to one week on the one hand, reduce the labor input on the other hand, improve the service life of the electrode plate, and improve the collection efficiency of the electrode plate in the long run.

$$\omega = \omega_0 \times (1 - r)^n \quad (1)$$

According to the above formula, after 360 days, the collection efficiency of electrode without automatic cleaning device decreased from 95% to 65.5%, while the collection efficiency of electrode with automatic cleaning device decreased from 95% to 84.5%.

Where, ω is the collection efficiency of the electrode sheet after n days, in%;

Where r is the average daily loss rate, in%, with values of 0.001 and 0.0003 respectively;

Where, n is the elapsed time, unit day, and the value is 360.

4. Conclusion

Application innovation: this device applies condensation technology, so that larger oil droplets can gather under the condensation of water and then be removed in large quantities, which greatly improves the oil collection efficiency;

Structural innovation: this device adopts the structure of condensation box, which realizes the collection of large oil droplets; The double-layer porous water pipe and the rotatable electrode plate are adopted to connect the shaft, which realizes the automatic cleaning of the electrode plate, prolongs the service life of the electrode plate and reduces the oil mist discharge.

Combining innovation: this device combines condensation technology and electrostatic adsorption technology to collect and treat all kinds of oil mist, which has great practicability and adaptability.

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