New Type of Smoke Purification Device in Smoking Room

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Abstract. In order to solve a series of problems existing in the existing smoking rooms in public places, such as poor indoor environment, the second-hand smoke is easy to adhere to the wall, tables and chairs, etc. In addition, the smoking room and the surrounding environment are easily polluted due to the low smoke collection and processing capacity. The device adopts the method of isolating and sucking the smoke by rotating jet shielding device, combining Nano crystalline adsorption with electro Fenton electrolysis the flue gas is treated. Compared with the traditional smoking room, it has better emission reduction benefits in reducing smoke emissions.

Keywords: Cigarette smoke, rotating jet shielding, electrofenton method, Nano crystalline.

1. Introduction

Cigarette smoke is one of the six major indoor air pollutants. The smoke is divided into mainstream smoke and tributary smoke, The harmful components of branch smoke were 3-50 times of that of mainstream smoke, But in a closed smoking room, Smokers inhale both mainstream and secondhand smoke, So it causes great harm to the body. And now, there is a problem that smoking rooms cannot isolate tobacco smoke, As a result, the outdoor air quality of smoking is extremely bad, If the smoke is not extracted in time, the walls, tables and chairs in the smoking room often have dirt attached to them, which is difficult to clean. Besides the existing flue smoke extraction equipment has the problems of high energy consumption and low efficiency.

Smoking is harmful to human health, but tobacco control can only be carried out step by step, The huge number of smokers needs a clean and environmentally friendly smoking room as a transition to no smoking, At present, there are still many problems in the smoking room, which cannot provide high-quality environment for all smokers. Based on this research background, the project team designs a device that can isolate the smoke in smoking room from non-smoking area, and has the device to purify the smoke in smoking room, so as to achieve the effect of smoke reduction in smoking room.

2. The main innovation points and key technologies of the project.

The innovation of this project is mainly reflected in the following aspects:

1) Structural innovation: The alternate grabbing structure can realize the synchronous adsorption and purification of the smoke adsorption device; the double gear structure controls the alternation of the grasping structure.

2) Functional innovation: The jet shielding effect can keep the wall clean continuously, and the flue gas suction has the function of processing and saving installation space.
3) Application Innovation: The rotary jet shield treatment of smoke inside the smoking room avoids the secondary pollution of the smoke; the electric Fenton is used for smoke treatment, which is efficient and environmentally friendly.

3. Structure and principle of the device

3.1. Overall design scheme of the device

![Semi sectional view of overall device](image)

Figure 1. Semi sectional view of overall device

The flue gas capture device is composed of two layers of trumpet shaped metal shells inside and outside. At the same time, the cylindrical surface is connected with the ventilation duct which blows inward. The inner metal shell passes through the gas treatment area above the device, and is pumped from the room by a fan. The gas capture device is connected with the metal box of the treatment part above, and there are dense nano crystalline plates in the pipeline at the connection part. The nano crystalline plates can enter into the electric Fenton reaction tank at the end of the treatment box alternately through the mechanical rotation mechanism, and the motor under the box can supply energy to the rotation mechanism through gear wheel drive. The pipeline at the end of the device is connected with two treatment tanks and finally flows to the tail activated carbon adsorption site.

3.2. Rotating jet shielding capture device

According to the types of smoking rooms in the current market, the investigation found that because of the defects of the smoking room itself and the reason of frequently opening and closing the door, and cannot catch and absorb cigarette smoke in time. As a result, a large number of flue smoke leaks. Therefore, this device designs a rotating jet shielding capture device to prevent the diffusion of flue gas and efficient collection. Figure 3. The rotating jet screen capture device is a two-layer hollow cylinder, the inner cavity is connected with the centrifugal fan at the top to provide lift to form updraft, and its suction inlet is circular; The outer cavity is connected with the branch pipe. The branch pipe is perpendicular to the cylinder axis and intersects with the cylinder. The exit end is a cone-shaped hollow cover, and it is a flat structure of 4-10 mm. The air collecting outlet is above the whole rotating jet shielding capture device to match the connected purification device. When the device works, the gas is driven by the forced draft fan, enters the external cavity of the hollow column along the branch pipe, and rotates along the outer cavity. At the exit, it enters the cone-shaped hollow cover, and finally ejects from the outlet. After being ejected, the airflow rotates until the bottom, converges to the center, and forms a vortex with the lift provided by the top centrifugal fan, constrains the smoke in the room and sucks it into the treatment device. The rotating jet will form a "wind shield" on the wall to isolate the indoor air from the outside, so that it will not leak from the smoking room and affect the non-smokers. In addition, the capture device can ensure that the smoking room is in a clean state, and the smoke is collected as soon as it is generated, so that Tar Nicotine will not adhere to the desktop and wall.
3.3. Smoke processing device

3.3.1. Smoke adsorption and filtration part. The smoke trapped by the rotating jet screen enters the filtration adsorption area composed of the adsorption area of nano crystalline in front and the adsorption area of activated carbon in the rear. The nano crystalline plate has hexagonal pore structure, in which can effectively adsorb suspended particles, tar, nicotine and other substances with small volume and strong adsorption capacity. The main function of activated carbon adsorption is to remove odor. The combination of the two can greatly prolong the use time of the adsorption module. The adsorption efficiency of activated carbon and nano crystalline plate can reach 97% to ensure that the flue gas can be fully absorbed and collected to complete the subsequent operation.

3.3.2. Mechanical shift part. After the adsorption of nano crystalline plate adsorption plate is full, it needs two sets of smoke adsorption and filtration mechanism, and the other set can be put into use immediately during the shutdown period of one set. The mechanical shift part is driven by the motor, and the air inlet can be used alternately by changing the left and right position of the wind shield. The power of the device is controlled by changing the gear position through the relay. The movable gear can move left and right to selectively drive the two sets of devices to work. The use of two sets of rotation device can effectively avoid the problem that the adsorption device cannot be used in the process of self-purification due to failure.
3.4. Oxidation treatment module of electric Fenton
The purpose of this part is to treat the smoke which is generated by the desorption of nano crystalline plate. The oxidation efficiency of tar and nicotine in Fenton is almost up to the 100%. The oxidation tank consists of anode, cathode, reactor and aeration plate. The anode is a kind of titanium-based electrode plate with tin antimony oxide as surface coating, its specification is 10cm×10cm, the volume of the cathode is 1cm×10cm×10cm, it’s made of carbon felt. The total reactor size is about 10cm×4cm×15cm, the aeration plate is installed at the bottom of the reactor to provide the gas needed for the reaction to ensure the full reaction.

![Figure 5. Oxidation treatment module of electric Fenton](image)

3.5. Control part of the whole device
The rotating jet shielding module is controlled by human body sensing and smoke sensing. When the smoke sensor detects smoke, the centrifugal fan and forced draft fan start and start to suck. When there is no human body induction, it will stop working after suction for a period of time.

4. Research basis and feasibility analysis of the project
As early as 1996, there have been relevant papers on the formation mechanism of tornadoes. At present, the theory of rotating jet shielding has been relatively complete. This theory has been studied in mineral mining and range hood by numerical simulation, and good results have been achieved. However, there are many interference factors in the mineral mining process, and the working condition of the range hood has not formed a closed environment. Whether the device can achieve the expected capacity needs to be further analyzed.

4.1. Feasibility analysis of jet shielding
The device uses rotating jet shielding device to absorb smoke in smoking room and form a barrier to prevent smoke from spreading to the outside. Therefore, it is necessary to demonstrate whether the rotating jet can complete the smoke extraction and restriction in the smoking room. The device injects into the cavity cylinder ring through the side to form the rotating gas, which is emitted from the jet port and enters the smoking room. The tangential force provided by the fluid viscosity drives the air in the whole room to rotate to form vortex. According to the literature, when the space height and width are 1.2 m and length L = 1.7 m, the gas is injected from the inlet at a velocity of 26.4 M / l and the swirl intensity Ω = 2.0, and the suction speed UZ = - 11.4m/s, etc. Here is a simulation study of these data:

The Continuity equation:

\[
\frac{\partial u_i}{\partial x_i} = 0
\]  

(1)

Reynolds equation
First of all, the adsorption capacity of nano compared with the nature of the hard
−ith the activated carbon treatment device in the
ng to organic matter
2−
𝜕
= 
\frac{𝜕}{𝜕x_j}
+ \frac{1}{\rho} \sqrt{\frac{2 \rho \varepsilon}{\mu}}
) \right) \frac{𝜕}{𝜕x_j}
(2)

Kinetic energy balance equation of turbulence:

\frac{\partial (\rho k)}{\partial x_i} + \frac{\partial (\rho k u_j)}{\partial x_j} = \frac{\partial}{\partial x_j} \left[ \left( \mu + \frac{\mu_t}{\sigma_k} \right) \frac{\partial k}{\partial x_j} \right] + G_k + G_k - \rho \varepsilon - Y_M
(3)

Kinetic energy dissipation equation of turbulent pulsation:

\frac{\partial}{\partial x_i} (\rho \varepsilon) + \frac{\partial}{\partial x_j} (\rho \varepsilon u_j) = \frac{\partial}{\partial x_j} \left[ \left( \mu + \frac{\mu_t}{\sigma_\varepsilon} \right) \frac{\partial \varepsilon}{\partial x_j} \right] + \rho C_1 S_\varepsilon - \rho C_2 \frac{\varepsilon^2}{k^2 + \varepsilon^2} + C_1 \frac{\varepsilon}{k} C_3 \varepsilon G_b
(4)

In the equation: p is fluid pressure; ρ is fluid density; VI and VJ are fluid velocity components; Xi and XJ are coordinate components; K is turbulent kinetic energy; ε is the turbulent energy dissipation rate; Gk is the turbulent kinetic energy generated by the laminar velocity gradient; Gb is the turbulent kinetic energy produced by buoyancy; YM is the wave generated by the diffusion of compressible turbulence. Through software data simulation, the results show that the flue gas can be effectively restrained and evacuated by the rotating jet in the environment of 1.2m × 1.2m × 1.7m. In the common smoking room, the length, width and height are close to the simulation data. The better restraint effect can be achieved by increasing the outlet diameter B0, changing the nozzle angle θ, the injection speed and the wind force.

4.2. Feasibility analysis of nano crystalline plate adsorption

The device uses nano crystalline plate as adsorption material. Compared with activated carbon, nano crystalline has great advantages as adsorption material. First of all, the adsorption capacity of nano mineral crystal is more than that of activated carbon. The reason is that the number of nano pores in nano crystal is much more than that of activated carbon with the same volume. The size of nano crystalline is about 0.3 ~ 0.9 nm, while that of activated carbon is about 2 ~ 50 nm. Therefore, the surface area per unit volume of nanocrystalline is much larger than that of activated carbon, and the amount of adsorbable pollutants is also greatly increased. Secondly, the pore surface of nanocrystalline has polarity, which can adsorb polar nano molecules more quickly and efficiently. Most harmful gases in the air are polar molecules, such as CO and nicotine in cigarette smoke, which can be effectively adsorbed. Most importantly, nanocrystalline can be desorbed in an environment above 45 °C, the adsorbed material can be discharged, and the nano-sized minerals can be reused. Compared with the nature of the hard desorption of activated carbon, it is more suitable for this device. At the same time, the device also uses this feature to enrich the pollutants in the smoke into the Fenton reaction tank to complete the oxidation treatment of pollutants. The adsorption efficiency of such adsorbents on impurities decreases with the increase of service time, however, the nano crystalline plate can be automatically desorbed in this device, so the efficiency can be maintained at a high level. With the activated carbon treatment device in the end, the adsorption efficiency of impurities can reach about 97%.

4.3. Feasibility analysis of electro Fenton process

The principle of Fenton method is that H2O2 is decomposed into OH− under the catalysis of Fe2+. Its oxidation potential reaches 2.8V. It decomposes organics into small molecules by electron transfer. At the same time, Fe2+ is oxidized to Fe3+ to produce coagulation precipitation, which can remove a lot of organic matter. Electro Fenton method is mainly combined with Fenton Method and electrocatalytic decomposition of water. H2O2 is obtained by electrolysis of water, which solves the consumption of hydrogen peroxide by ordinary Fenton Method and increases the factors leading to organic matter degradation. Besides hydroxyl radical oxidation, there are also anodic oxidation and electro adsorption, so as to enhance the removal effect and reduce the cost. According to the literature, the efficiency of

\frac{\partial (\rho \varepsilon)}{\partial t} + \nabla \cdot (\rho \varepsilon \mathbf{v}) = - \frac{1}{\rho} \frac{\partial \rho \varepsilon}{\partial t} + \frac{\mu}{\rho} \frac{\partial v_i}{\partial x_j} + \frac{1}{\rho} \frac{\partial}{\partial x_j} \left[ \frac{\rho \varepsilon v'_i v'_j}{2} \right]
various organic matters can reach more than 70%, and some can reach 98%. Based on the above discussion, it can be seen that the electro Fenton method should have good removal effect for the main organic harmful components of cigarette smoke, such as tar and nicotine.

4.4. Economic cost feasibility
The price of nano crystalline ball in the existing market ranges from 4 RMB / kg to 10 RMB / kg, and the price of the prepared nano crystalline plate is about 100 RMBn / piece according to different specifications. In addition to the need for power supply, the main working material of the electric Fenton reaction tank is iron carbon filler, which has wide purchasing channels, low price and ideal economic cost. The price of the device is mainly concentrated on the motor and blower, and the overall financial budget of the device is about 5000 RMB. The other structure of the device is conducive to maintenance, and the maintenance and replacement of nano crystal plate and iron carbon filler are also very convenient. Therefore, the economic cost of both production and later maintenance is relatively low.

5. Benefit analysis

5.1. Benefit analysis of energy saving and emission reduction
According to the literature results, the ratio of mainstream smoke to tributary smoke is 5:1, the ratio of carbon monoxide concentration of mainstream smoke after human exhalation to that of tributary smoke is 1:15, and the ratio of carbon monoxide exhaled from mainstream smoke to non-exhaled carbon monoxide is 29:55. When an ordinary cigarette burns, it will produce a volume of 900ml and a carbon monoxide concentration of 12000mg/m3 under standard atmospheric pressure. However, the concentration of carbon monoxide in the room is required to be no more than 10mg/m3. The existing exhaust system of the traditional smoking room generally absorbs about 40% of the smoke. The device of the project team adopts the rotating jet shielding device to control the smoke in the smoking room According to the literature, the smoke absorption rate is 99%. There were 12000 people in the smoking room of Changsha airport within a week, We calculate it according to one cigarette per person, and Suppose that the CO’s mass of a mainstream cigarette is $M_1$, Branch of smoke’s CO’s mass is $M_2$. Total mass of carbon monoxide produced by smoke M. The device can reduce the air volume of carbon monoxide pollution in the nearby non-smoking area by the traditional smoking room V.

$$M_1 = 900 \times 16 \times 10 - 6 \times 12000 \times 2955 = 5.17 (mg) \quad (5)$$

$$M_2 = 900 \times 16 \times 10 - 6 \times 12000 \times 15 = 28.89 (mg) \quad (6)$$

$$M = (M_1 + M_2) \times 1.2 \times 104 = 408720 (mg) \quad (7)$$

$$V = M \div 10 \times 59\% = 24114.48 (m^3) \quad (8)$$

Compared with the traditional smoking room, the device can reduce the air pollution of 24114.48 m$^3$ in the nearby non-smoking area.

5.2. Benefits in social
At present, the sealing effect of the traditional smoking room is poor, and the smoke smell in the smoking room can still be smelled in some public places, which is very unfriendly to the people who come and go. In addition, the purification effect of the indoor smoke environment is not good, leading to the smokers themselves not willing to smoke in the smoking room. The device can avoid the occurrence of the above problems for the smoke in the smoking room and provide the public with a good air environment.
6. Application prospect
According to the 2018 China Adult Tobacco Survey Report, there are more than 350 million smokers in China, if we want to achieve a comprehensive indoor smoking ban, it is neither necessary nor practical. The device can purify the air in the smoking room and avoid the pollution of the concentrated smoke in the smoking room to the environment in a certain outdoor area, and it protects the health and living environment of non-smokers, and the most important thing is that it gives respect and protection to both smokers and non-smokers. There is a good application prospect.

7. Conclusions
The new smoke purification device of the project overcomes the existing problems such as poor indoor environment of smoking room, second-hand smoke is easy to adhere to walls, tables and chairs, and low smoke collection and processing capacity, which results in pollution of smoking room and surrounding environment. Through the calculation and analysis of flue gas flow during entrainment, a reasonable purification method is designed to meet the flue gas purification function, achieve better energy saving and emission reduction effect, and reduce environmental pollution, which has high practical significance.

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