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Heat Transfer Electric Precipitator and Its Dust Collecting Plate Dust Settling Force Analysis and Re-entrain Dust

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ABSTRACT：this paper presents a new type heat exchange electric dust collector, analyzes its dust collecting plate from the Angle of microscopic dust particles by van der Waals force, adhesive force and electrostatic force and thermophoresis force, through the establishment of the dust particles of dust collecting plate and bond model, analyzed the dust settling on dust collecting plate force of attraction and backmixing, puts forward the conditions of the dust particles can be returned to the airflow. The experimental results show that the device has superior cleaning performance, can effectively curb the reentrainment of dust.

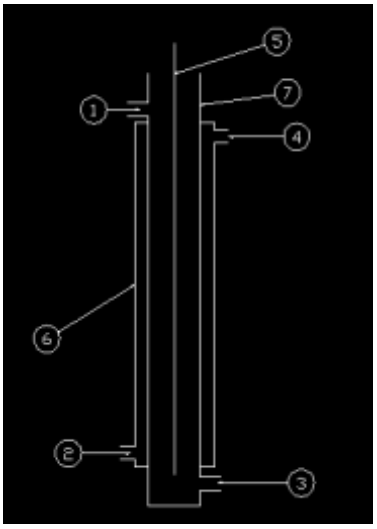
KEYWORDS：Heat transfer electric precipitator, dust particles, dust collecting plate, Bond model, re-entrain dust

I. INTRODUCTION

Dedusting technique with electricity is widely used in industry, the traditional electrostatic precipitators of PM10 above particle removal efficiency is higher, but for the collection of fine particulate matter ,because of the shortage of charged and the reentrainment of dust, etc.the dust collection efficiency is unsatisfactory. J.R melcher and Y.z huang etc. Think about 30% of escape from the electric dust is caused by reentrainment of dust[1].Has been collected dust will happen reentrain depends on the force of the dust particles,When adhesion strength is greater than the stripping force, dust particles can be securely attached, or they may fall off again into the air.Such as, the dust deposition layer often for cohesive force is too small and the airflow to scour, particle method to rebound or reverse the effect of electrostatic force and regurgitation, or because the cohesive force is too large, strong vibrating force to the dust from the dust collecting pole fell down.But at this time could make the original has formed the massive dust deposition layer was break, hence the particles return flow is much larger than when conventional shaking.Even no vibration and beating, dust particles may not stay in the place where the deposit, and may even backmixing again into the air.When vibrating dust collecting plate, especially fine particles are easy to produce dust secondary dust, seriously affect the dust collecting efficiency.Efficient dust removal of PM2.5 particles technology research has become the development direction of the electric technology and current research hot spot[2] .

II. STRUCTURE DIAGRAM

The shell to make double electrostatic precipitators, interlayer cooling water, layer is a dust collecting wall and the heat transfer surface, dust and heat exchange between the role of can promote each other organically as shown in figure 1. Because of heat exchange effect, the dust stream with certain temperature difference exists between the dust collecting plate, dust was forced from high to low temperature zone, produce thermal subsidence, promoted the dust collecting. Dust collecting plate surface temperature is lower than another stream temperature effect is produced can restrain the phenomenon of back corona.



Heat transfer electric precipitator structure schematic diagram

①- air inlet; ②- water inlet; ③- the outlet;④- outlet; ⑤- corona pole; ⑥- outer cylinder; ⑦inner barrel

1THE FORCE ANALYSIS OF DUST COLLECTING PARTICLE

Attached to the solid surface dust particles, or particles attached to each other is called adhesion. To overcome the adhesion phenomenon needed to force (vertical acting on the particle centre of gravity)is called adhesion force. For the device, dust particles were in thermoelectric composite field, the influence of dust particles and dust collecting plate stress mainly (not including chemical adhesive force), van der Waals force, capillary adhesion force, electrostatic force and thermophoresis force [3].

1.1 Van der Waals force

According to the theory of van der Waals force formation, neutral atoms and symmetry with the instantaneous dipole, it is because of the electron cloud of fluctuations around the nucleus, the instantaneous dipole make the neighboring atoms or molecules produces dipole. By quantum theory can calculate the gravitational force. Van der Waals force between spherical particles with spherical particles F_V formula (1) can be used to calculate, and van der Waals force between the spherical particles and collecting plate can be calculated by d as infinity [4].

$$F_V = \frac{H}{12z^2}\frac{d_1 d_2}{(d_1 + d_2)} \tag{1}$$

In the formula , H as van der Waals force constant, H = 2.4 x 10^{-20} j; d_1 and d_2 as the diameter of two spherical particles, m.Van der Waals force between particles and plate, equivalent to any of the d_1 and d_2 tends to infinity,

$$F_V = \frac{H}{12Z^2} d \tag{2}$$

In order to pell the single partic which attached to the dust collection plate, suppose you want to dozen of vibration acceleration for a:

$$F_V = \mathrm{m}a = aV\rho \quad \text{(3) namely}$$

$$\frac{H}{12Z^2}d = a\frac{4}{3}\pi\left(\frac{d}{2}\right)^3\rho, \qquad \alpha = \frac{H}{2Z^2\pi\rho d^2} \tag{4}$$

Formula (4) show that the particle size, the greater the need of vibrating acceleration is smaller; The smaller the particle size, vibrating acceleration, the greater the need when vibrating acceleration vibration increases and to make fine dust fall, will produce the secondary dust. Therefore, fine dust particles is not easy to fall into vibration, van der Waals force plays a role.

Assume that the distance between particles or particles to plate the smallest distance between z = 4 x 10^{-10} m, can respectively calculate the particle diameter in the range of 0.1 ~ 000.0μm between particles and particles with the size of the van der Waals force between the plates, as shown in figure 2.

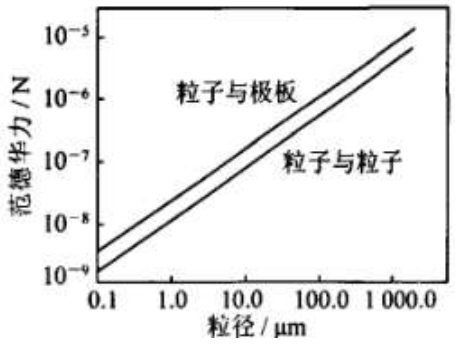


Figure 2 the relationship between van der Waals force and the diameter of the particles

1.2 Capillary adhesion force

Due to the humid air, in the gap between the two contact bodies can produce the water vapor condensation (as shown in figure 3), formed in the clearance of the meniscus pull particles to the surface. The tension of the particles is derived from the two aspects, one is the surface tension, the second is capillary action reduces the liquid pressure on the outside. This tension is for particles increase adhesion, it can be written as the sum of two parts:

$$\mathrm{F_f} = \mathrm{F_{iv}} + \mathrm{F_p} \tag{5}$$

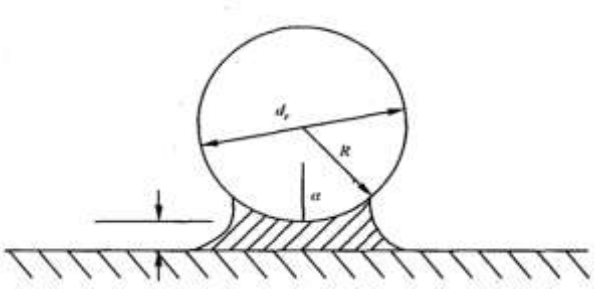


Figure 3 capillary force diagram

In the formula, F_f is total tension due to the presence of water, F_{iv} is the surface tension, F_p is capillarity or capillary pressure produced by the Laplace pressure [5]. Thus there are:

$$F_f = 4\pi R\gamma_{iv}\sin\alpha\sin(\theta+\alpha) + 4\pi R\gamma_{iv}\cos\theta \tag{6}$$

θis the contact Angle, α Angle usually is very small, so the first item is not important, for infiltrating liquid cosθ= l, so,

$$F_f = 4\pi R\gamma_{iv} \tag{7}$$

or

$$F_f = 2\pi d\gamma_{iv} \tag{8}$$

Formula of F_f for capillary adhesion force, N; γ_{iv} to the water's surface tension, the general is 0.072 N/m, d for dust diameter, μm . for particles d = 1 m, $F_f = 4.5 \times 10^{-7}$ N [6].

This force compared to the van der Waals force is important. Oil mist in the air will be condensed during the particles and the surface of the gap between a meniscus that also will increase the adhesion of particles adhesion, capillary force contrast van der Waals force is much larger, so in the presence of capillary force, its size played a dominant role its size, this conclusion also got many theories, and experimental verification.

1.3 The electrostatic force

Under normal circumstances, the dust particles charged by nature of the influence of the bond force is not very big, but in the electric, the electrostatic force on dust particles collected plays a vital role. Dust particles is affected by the applied electric field, and combined with the nature of the dust particles difference is bigger, so the complicated situation of dust by electrostatic force. Generally, the electrostatic force of the dust can be divided into corona electrostatic force, polarization electrostatic force, contact electrostatic force and induction electrostatic force.

1.3.1 corona electrostatic force

Dust particles under the action of electric field force, the dust collecting pole movement and deposition on the dust collecting pole. Because of the dust particles of the insulation resistance is not infinite, take charge of saturated dust particles, reach the dust collecting pole began to leak charge, the dust deposition layer can be regarded as leaky capacitor, the capacitor is plate for ground dust collecting plate, the cathode is composed of negatively charged dust particles. The electrostatic leakage of dust layer to capacitance discharge rule, namely

$$Q = Q_0 e^{-t/(\rho\varepsilon_d)} \tag{9}$$

W here Q at time t charge amount of dust particles, C; ρ is the specific resistance of dust, Ω.Q_0 is charged particle electric field saturated load capacity.

$$Q_0 = 4\pi\varepsilon_0\left(1+2\frac{\varepsilon_d-1}{\varepsilon_d+2}\right)d^2E_0 \tag{10}$$

After dust particles reach the dust collecting pole by corona electrostatic force is

$$F_d = QE_0 = Qe^{-t/(\rho\varepsilon_d)}E_0 = 4\pi\varepsilon_0\left(1+2\frac{\varepsilon_d-1}{\varepsilon_d+2}\right)d^2{E_0}^2e^{-t/(\rho\varepsilon_d)}, \tag{11}$$

Where, ε_0 is permittivity of free space, $\varepsilon_0 = 8.85 \times 10^{-12}$ C / (V · m); ε_d relative permittivity dust (dimensionless); E_0 is the applied electric field strength, V / m.

1.3.2 polarization electrostatic force

Polarization of dust particles in field intensity of an electric field is made up of E_0 and dust particles produced by the bound charge on the additional electric field.Additional electric field in dust particles inside the ball, with the original electric field in opposite directions. According to the principle of superposition of field,

particle ball total electric field is weaker than the original electric field; Both non-polar molecules are polar molecules, as long as the polarization phenomenon occurs in the electric field. Polarization bound charge dust particles can produce the effect of electrostatic force F_j.Its calculation formula is

$$F_j = 2\pi d^3 \varepsilon_0 \frac{\varepsilon_d - 1}{\varepsilon_d + 2} grad E_d^2 \tag{12}$$

Where, E_d is the electric field strength of the dust layer. Collecting dust particles deposited on the plate by electrostatic polarization and its spatial resolution in which the electric field intensity squared related to static electricity and the polarization direction toward the direction of the electric field becomes strong. Polarization static electricity strengthened the bond between the particles.

1.3.3 contact electrostatic force

In 2 surface must contact potential difference places will exist a electric field. Assume that nonlinear process (breakdown) electric field strength reached the maximum Emax, and the collision of particles considered point contact form, as shown in figure 4.

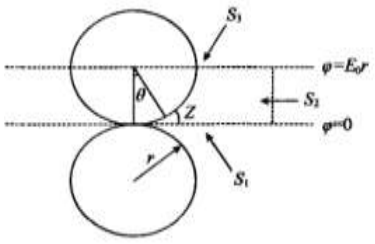


Figure 4 dust particles contact model

θ- particle contact radius of the central Angle; Z - contact radius edge
To the horizontal plane distance; S1, S2, S3, dust particle contact respectively
Three closed near the cylinder surface

If the space is lesser, between the two surfaces of the electric field may be very high, the ion or smaller Charged ions in motion or force will produce very big effect. Contact electrostatic force F_Z calculating formula for of electrostatic force is

$$F_Z = 0.42\pi\varepsilon_0 d^2 E_{\max}^{0.8} E_0^{1.2} \tag{13}$$

Where d is the diameter of a spherical particle, m; gas breakdown electric field strength E_{max} of the time, KV / cm, E_{max} desirable value 20KV / cm, under conditions known outside the field intensity can be obtained with different diameters dust suffered electrostatic particle contact.

1.3.4 induction electrostatic force

For low resistivity dust, because has good electrical conductivity, carries a negative charge soon by dust collecting plate leak out, and the electrostatic induction and bring the same as the dust collecting plate positive charge .at this point, the dust particles of opposite direction, the direction of the electrostatic force with the original is a repulsive force, this force makes the dust out of the dust collecting plate and return airflow, its value can be calculated with the formulas below, namely

$$F_i = 0.832 \frac{\pi^2}{6} \varepsilon_0 \varepsilon_d d^2 E_0^2 \tag{14}$$

In plus field under the condition of 3, 5, 7 KV/cm, respectively, to calculate the different diameter dust grain induction of electrostatic force (figure 5)

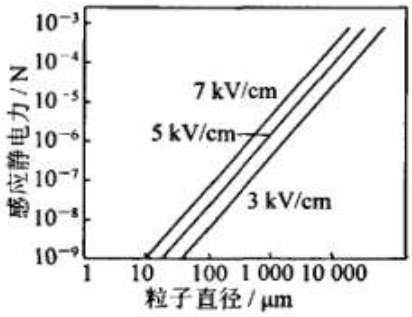


Figure 5 The relationship of induction electrostatic force, the particle diameter and ppliedvoltage

1.4 the thermophoresis force

The high temperature fluid molecule collision more than low temperature, so the particles by thermal pressure from high temperature and low temperature zone migration, this force is called the thermophoresis force. Through the predecessors' research results show that the thermophoresis force with temperature gradient of the flow field in the movement of the tiny particles is important, when particle size less than 10μm, he began more than gravity.here use Epstein thermophoresis force formula calculation [7].

$$F_{th} = \left(\frac{9\pi}{2\rho T_g} \right) d\ \mu^2 \left(\frac{k_g}{2k_g + k_p} \right) \frac{dT}{dx} \tag{15}$$

ρ is the gas density, d is the particle diameter, μ is turbulence viscosity, k_g, K_P is the coefficient of thermal conductivity of gases and particles, T_g is gas temperature.

Using the thermophoresis force effect of the temperature field is the removal of fine particulate matter especially submicron is an important way of fine particulate matter,Chang-Fu You of the tsinghua university (2010) design of wet electrostatic dust removal system in the use of electrostatic field makes particles by airflow movement center to the surface dust collecting wooden partition boundary layer, using high temperature flue gas and dust collecting plate produced by the difference in temperature on the thermophoresis force increase near the surface of particle capture, significantly improve the fine particulate matter especially the capture efficiency of submicron particles.

2. Mechanical model

Look from the action effects of dust, van der Waals force, adhesive force and before the thermophoresis force and electrostatic force is make dust adhesion on dust collecting plate and induction electrostatic force dust out of the dust collecting plate. In order to analyze problem statement on convenience, the former three kinds of electrostatic force are collectively referred to as binding gravity (Fe), induction electrostatic force is called binding repulsion (F_C), to build a bond model composed of dust particles and dust collecting plate as shown in 6.

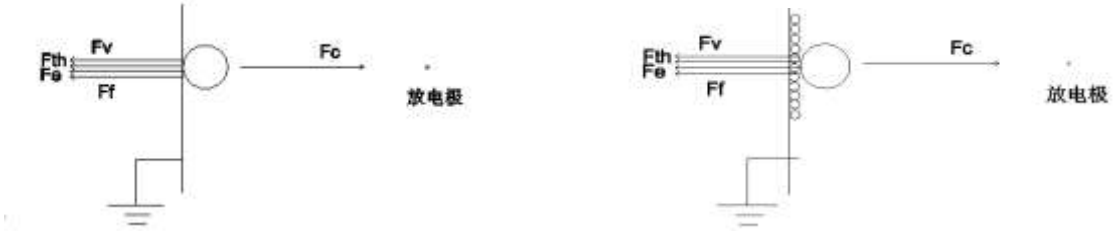


Figure 6 Dust particles bonding model

The bond force equilibrium equations for the model

$$F_c = F_{th} + F_f + F_e + F_v \tag{16}$$

When $F_c > F_{th} + F_f + F_e + F_v$, said dust is greater than in the guide attached to the force of repulsion, dust adsorption on dust collecting plate, on the other hand, when the $F_c < F_{th} + F_f + F_e + F_v$, said dust by attractive than by repulsion, dust will be out of the dust collecting plate, the dust deposited on the dust collecting plate will backmixing particles into the air, or the phenomenon of . re-entrain dust.The theoretical calculation results show that when the dust particle size is 100μm or smaller particles, dust will not be returned to the mixed into the air. But when the dust specific resistance less than 10^4Q·cm or dust particle size is larger, the dust is easy to return to mix into the air.

III. CONCLUSION

(1) through the analysis of the cohesive force of particles by size calculation formula of dust particle binding model, analyzed the dust deposition on the dust collecting board of appeal and backmixing force, put forward the necessary for secondary dust can occur.

(2) dust particles by adhesive power to decide whether it again to return to the dust in the air, to contain dust backmixing can increase the adhesion strength of dust, for the purpose of this article, introduced the thermophoresis removal technology, on the basis of realize the hot dust removal, increase the thermophoresis force dust adhesion of gravity, which would strengthen the dust catcher, inhibit the generation of re-entrain dust.

(3) the thermophoresis force effect of removal of fine particles is an important way, but in the basic research stage at present, there have been no mature and feasible technology, application of thermophoresis removal of fine particulate matter experimental research are very few, and pure thermophoresis effect caused by the deposition efficiency is not high, from the point of the experimental and theoretical research results at home and abroad, pure thermophoresis effect of top dust removal efficiency is only 30% or so, in this paper, heat transfer type dust collector, a feasible direction is proposed.

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