SOLID PARTICLES SEPARATION FROM SMOKE STREAMS WITH THE HELP OF ELECTROSTATIC PRECIPITATORS POWERED BY AC VOLTAGE

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ABSTRACT

This paper deals with the possibility of charging and transporting macroscopic particles in AC electric field. The model of electric precipitator with dielectric collector electrode powered by AC high voltage was constructed and tested in a great number experiments. The precipitation efficiency of this model for three types of dust with specific resistivity in range of 10^0*–*10^6 *Ω.m was tested. The possibility of the usage of the electrode systems with barrier in practice is shown in this paper.*

1. INTRODUCTION

In present days there is a number of precipitator types, though the most used are high voltage electric precipitators powered by DC high voltage, since they are able to ensure high clearance of gas stream. A high voltage precipitator powered by DC voltage works best, if the specific resistance of solid contaminant has the size in a certain range. When the electrophysical properties of separated media do not fit the requirements of precipitation processes with DC supply, it is necessary to find other technological procedures. One of them seems to be the precipitation with AC voltage.

2. THE REASON OF AC VOLTAGE APPLICATION

The electric precipitator with direct voltage works best if the specific resistance of contaminant is in the range from 10^2 to 10^{10} Ω.m [2]. If the specific resistance of a contaminant is higher, with a great possibility a back-corona arises in precipitator, and consequently the effectivity of separation decreases and discharges rise in interelectrode area [4]. On the other hand if the specific resistance is lower, the particles are very quickly discharged when they reach the collecting electrode and they are plucked back again by gas stream. In such cases an application of AC voltage supply for electrostatic precipitator is more suitable. That was the main reason for starting thinking about their utilization.

The electrostatic precipitator powered by AC voltage needs for its regular operation a barrier in interelectrode area which among others prevents the creation of back-corona and when it separates a dust with low specific resistance, it ensures the immediate dischargeing of the particle at the moment of reaching and subsiding at the collecting electrode, so it is not plucked back by streaming gas. Consequently the AC voltage is suitable for contaminant separation with high as well as low specific resistance.

3. THEORETICAL ANALISYS OF MACROSCOPIC SIZED PARTICLE DYNAMICS

The motive to solve the kinetic equations (path, velocity eventually acceleration) originates from spherical shape particles application technology, eventually the particles of rotary elipsoid or short pipeline shape [6], [8].

The starting point for kinetic equation solution are real conditions that occur with particle deposition technology providing the particles capture a charge by [6]:

- corona charging,
- contact charging.

The simplified set-up of the equipment is shown on Fig. 1.

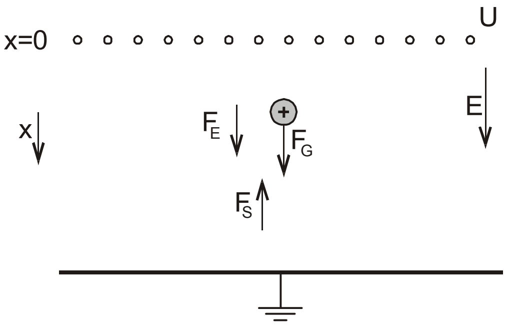


Fig. 1. The set-up of experimental equipment for particle deposition

Providing a transport area in which the electric field is semihomogeneous, we can express the equation of force effects on a particle:

$$F = F_E + F_G - F_S \tag{1}$$

where F – is the overall force that affects a particle
F_E – is the force of electric field
F_G – is the gravity force
F_S – is the Stokes force

Comparing these forces, electric field force plays a dominant role [6]. From the force effects balance, after substitutions for respective forces and after integration and some mathematical adjustments we get the final equation for the path of a macroscopic particle in DC electric field:

$$x(t) = \frac{m}{6\pi\eta r}\left[v_0\left(1 - e^{-\frac{6\pi\eta r}{m}t}\right) + \frac{QE + mg}{6\pi\eta r}\left(e^{-\frac{6\pi\eta r}{m}t} + \frac{6\pi\eta r}{m}t - 1\right)\right] \tag{2}$$

By differentiating of equation 2 we get the expression for the velocity of a macroscopic particle in DC electric field:

$$v(t) = v_0 e^{-\frac{6\pi\eta r}{m}t} + \frac{QE + mg}{6\pi\eta r}\left(1 - e^{-\frac{6\pi\eta r}{m}t}\right) \tag{3}$$

Time dependeces of path and velocity of a particle are shown in Fig. 2 and Fig. 3.

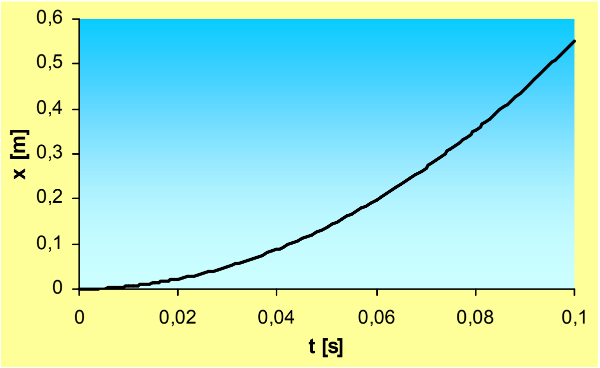


Fig. 2. Time dependence of the path of a particle in the case of DC voltage

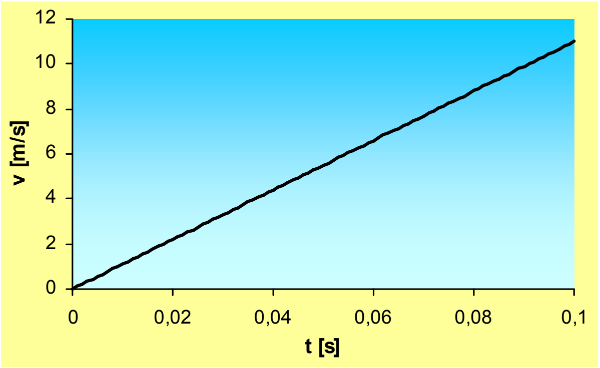


Fig. 3. Time dependence of thevelocity of a particle in the case of DC voltage

The starting point of kinetic equation solution for particles in AC electric field is the same balance of force effects and we consider an AC electric field with sinusoidal vaweform of 50 Hz frequency. We use the same procedure as with a DC electric field and we get an equation for the path of a particle in AC electric field:

$$
\begin{aligned}
x(t) = {} & \frac{g}{A^2}\left(e^{-At} + At - 1\right) + \frac{v_0}{A}\left(1 - e^{-At}\right) + \frac{K}{A\omega}\Big[\cos\psi - \frac{1}{A^2+\omega^2}\cdot \\
& \cdot\left(\omega^2 e^{-At}\cos\psi - A\omega e^{-At}\sin\psi + A\omega\sin(\omega t+\psi) + A^2\cos(\omega t+\psi)\right)\Big]
\end{aligned} \tag{4}
$$

and for the velocity:

$$
\begin{aligned}
v(t) = {} & \frac{g}{A}\left(1 - e^{-At}\right) + v_0 e^{-At} + \frac{K\omega}{A^2+\omega^2}\cdot \\
& \cdot\left[\frac{e^{-At}}{\omega}\left(\omega\cos\psi - A\sin\psi\right) - \frac{1}{\omega}\left(\omega\cos(\omega t+\psi) - A\sin(\omega t+\psi)\right)\right]
\end{aligned} \tag{6}
$$

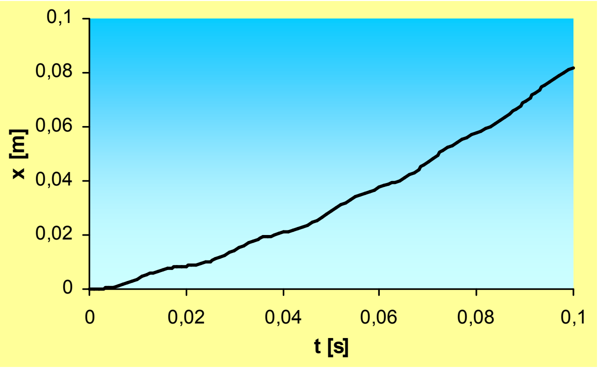


Fig. 4. Time dependence of the path of a particle in the case of AC voltage

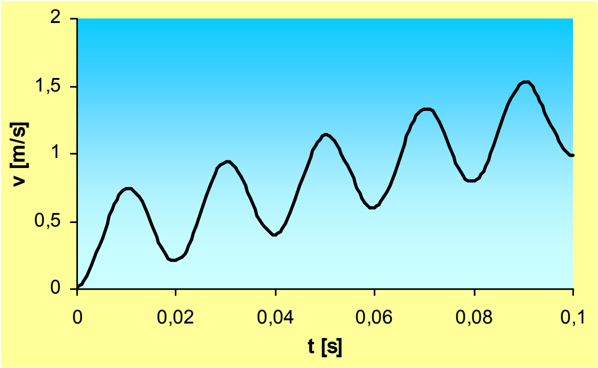


Fig. 5. Time dependence of thevelocity of a particle in the case of AC voltage

Their time dependeces are shown on Fig. 4 and Fig. 5.

4. PARTICLE SEPARATION IN AC ELECTRIC FIELD

The macroscopic particles diffused in the area of coronating electrode, which is connected to AC high voltage, are not charged, as we assumed [2]. For that reason it is necessary to create electrophysical conditions for unipolar electric charge creation in the area of feeder mouthing. One of the possibilities is the application of physical effect on metal – dielectrics – gaseous medium interface [6]. Two electrode systems were designed based on this principle:

- system with a dielectrical coronating needle and metallic collector electrode
- system with a metallic coronating needle and dielectrical collector electrode.

In the first case a metallic needle with small radius of curving, equipped with an additional insulating needle (PE, glass) with various values of relative permitivity is used as coronating electrode. With a more detailed analysis it can be proved, that between metallic needle ended with dielectic material and collector a combination of capacitances is created (Fig. 6), from which a dominant role plays a capacitance made by a dielectric cone on metallic electrode [6]. Unipolar charge is generated on the surface of dielectric cone, whose polarity and size depends on dielectric properties of used material (polarization, conductivity etc.), assuming that the surface resistance Rdx→∞. By application of materials listed above a charge on the surface of cone shape is generated with a high concentration at the tip. A corona is generated on the composed coronating electrode and in its surroundings an unipolar space charge is formed (Fig. 7), which causes the same charge of macroscopic particles in the surroundings of the needle. The particles charged by this manner are transported by force effects of electric field to collector electrode.

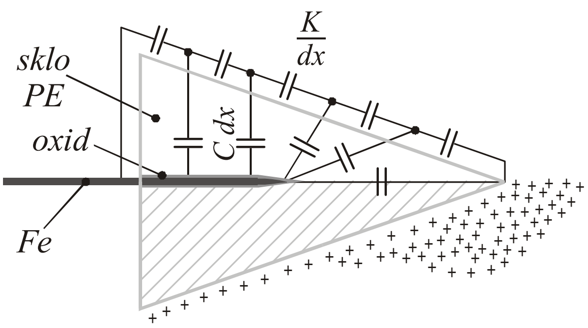


Fig. 6. Replacement model of dielectric needle

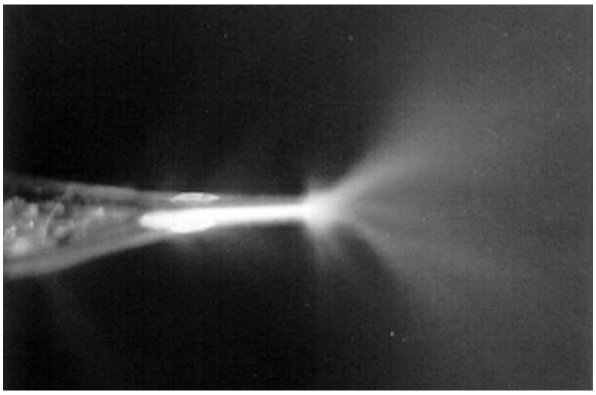
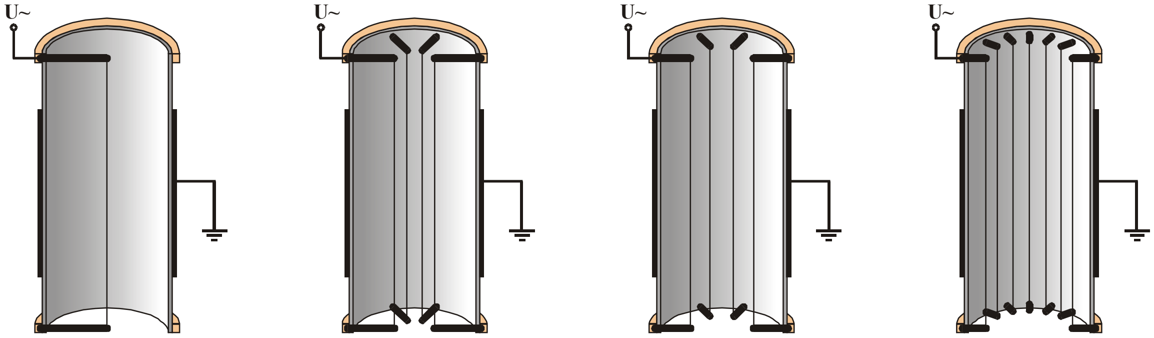


Fig. 7. Photographic shot of corona in the surroundings of dielectric needle

In the second case a cascade coaxial precipitator was constructed for the experiments. Tha cascade consisted of four sections (Fig. 8). A PVC pipeline forms their skeleton, serving at the same time as collector electrode. A thin aluminium foil is sticked to the outer side of the pipeline serving as grounded electrode.



1. section 2. section 3. section 4. section

Fig. 8. Geometric ordering of sections in cascade pipeline percipitator with AC voltage

A thin copper line wire is fastened inside the pipeline, so that it forms the ionization electrode. Each section of the cascade contains a different number of coronating electrode and they are placed in different span from the collector electrode. The role of ionizating electrode is the creation of highly inhomogeneous electric field. It is possible to create such a field with the help of electrodes with a very small radius of curving. When the coronating electrode is polarized positively, new electrons resp. new fotons are released at the moment of giving off the kinetic energy, following the cannonading of the needle by electrons, which causes future ionization. The situation is analogous under negative polarization with the difference, that avalanches emitted from negative needle are transported into increasingly homogeneous field, and consequently their mobility and ability to ionizate decreases.

In AC separation processes with metallic needle an insulation barrier is used as collector electrode. To achieve the best possible separableness it is necessary to choose insulation materials with the highest possible specific resistance and permitivity. However the choice of material depends on other nonelectric parameters e.g. the temperature of gas streams, sufficient mechanic robustness (due to strikes) etc. The insulation barrier must not change its mechanic nor dielectric parameters due to temperature changes.

A number of experiments were carried over on these models:

- Initial measurements: based on electric field modelling in interelectrode area, so the right distance between coronating electrode and collector electrode could be chosen. Furthermore an acceptable voltage connected to coronating electrode was chosen, so as no flash-over appears between high voltage electrode and ground.

- Measurements without dust: mainly V-A dependence measurements of the electrode system.
- Measurements with dust: during these measurements the precipitator was powered by AC voltage, a measured amount of dust was equally dispersed through feeder into the precipitator and the separableness was stated based on the amount of dust that falled trough. At the same time the current flowing throug the precipitator was measured.

To find out the separableness of the models of AC precipitators, three types of dust were used with specific resistance 3 Ω.m, 4 kΩ.m and 4,8 MΩ.m. With the model of 30 cm in length 60 % to 97 % average value of separableness was achieved with all types of dust (Table. 1).

	Separableness [%]			
	1. section	**2. section**	**3. section**	**4. section**
Dust with ρ_e= 3 Ω.m	83,16	70,72	73,94	62,02
Dust with ρ_e= 4 kΩ.m	96,82	81,72	83,7	72,12
Dust with ρ_e= 4,8 MΩ.m	93,45	93,56	97,82	95,14

Table. 1 Average values of separableness in particular sections of the cascade pipeline precipitator powered by AC voltage

It can be observed that the separation process with AC voltage is comparable to separation with DC voltage and under certain conditions better separation can be achieved with AC voltage.

5. CONCLUSIONS

The possibility of AC voltage application for macroscopic sized particle separation was described in nonconventionally ordered electrode system: coronating electrode – dielectric barrier as collector – grounded electrode, eventually dielectric needle on metallic electrode – grounded metallic collector electrode. These systems exploit physical phenomena from the theory of high voltage field with a barrier. The advantage of these systems against to DC voltage powered systems is especially in economics of separation process regulation. This can be an important step to a wider utilization of this technology in practice.

6. REFERENCES

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