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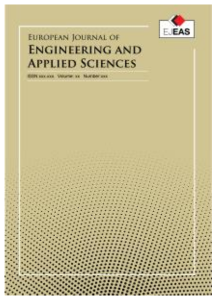

Research Article

The Mathematical Modeling of the Charging and Deposition of Aerosol Particles in a Corona Field

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Abstract: In this study, we derive some mathematical expressions that allow us to determine the proportion of charged aerosol particles in the corona, as well as analyzed the conditions of deposition of charged particles uniformly distributed in the space between the discharge and collecting electrodes. The numerical implementation of this method confirms its acceptable accuracy compared to known methods in the literature. The obtained results indicate that, under suitable conditions, use of a corona field can be an alternative technique for cleaning and refining impure aerosol mixtures for desired purposes.

Keywords: *Aerosol particles, corona field, mathematical modeling,*

Corona Boşalmasında Aerosol Parçacıklarının Yüklenmesi ve Birikmesinin Matematiksel Modellenmesi

Özet: Bu çalışmada, corona boşalmasında oluşan yüklü aerosol parçacıklarının oranını belirlememize olanak sağlayan bazı matematiksel ifadeler türetilmiştir. Ayrıca deşarj ve toplayıcı elektrotlar arasındaki boşlukta düzgün bir yük yoğunluğu dağılımına sahip yüklü parçacıkların çökelme koşulları analiz edilmiştir. Bu yöntemin sayısal uygulaması, literatürde bilinen yöntemlerle karşılaştırıldığında kabul edilebilir doğruluğunu teyit etmektedir. Elde edilen sonuçlar, uygun koşullar altında, corona alanının kullanımının, saf olmayan aerosol karışımlarının istenen amaçlar için temizlenmesi ve rafine edilmesi için alternatif bir teknik olabileceğini göstermektedir.

Anahtar Kelimeler: *Aeresol partiküller, corona boşalması, matematik modelleme*

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1. Introduction

Continuing technical progress requires the use of technological processes based on the most recent scientific developments. In this respect electron-ion technology is finding wide usage in various branches of industry and agriculture.

Technological processes, such as electro-separation, electro-precipitation and electro-coagulation are based on the movement characteristics of charged aerosol particles in the electrical field and the interaction between the electrical field and the charged particles of the material [1-4].

Currently, the most widely used method in charging aerosol particles in electron-ion technology is the charging of the particles in a volume charged electrical field or charging by high voltage electrode contact [5-12]. As is well known, charging of the particles in a volume charged electrical field consists of these two processes: field charging and diffusion charging respectively. The degrees of intensity of these processes are different and they depend on the geometric dimensions of the particle. For example, the field charging is more effective for the particles having dimensions larger than~3μm and diffusion caused charging processes can be neglected for the particles having these dimensions. In this paper we consider the charge and deposition of aerosol particles in the corona.

2. Statement of the Problem

Get the modified equation charging and deposition of aerosol particles in a strong electric field and to realize the numerical solution for the effectiveness of the charging particles in the corona discharge, depending on the composition of the dispersed particles and the parameters of the electrical discharge.

3. Theory

The absorption of charges from corona region may be determined based on the molecular kinetic theory of gases. In this case the absorption of charges from corona region may be determined by using on the molecular kinetic theory of gases. Assume that the volume of gas V- contains N uncharged particles ellipsoidal shape having a mass- m, with a specific gravity of- γ.

As is known, the length of the mean free path of the particle λ- mathematically expected distance at which the particle motion in the electrostatic field flies without collisions with other particles. Assuming that the collision with the ion plasma flow channel particle is eliminated from the process, it is possible to determine a decrease in the amount of charge in the path dx follows

$$-dq = q\frac{dx}{\lambda} \tag{1}$$

Integrating this equation we get

$$q = q_0 \exp\left(-\frac{x}{\lambda}\right) \tag{2}$$

Where q_0- initial amount of electricity in the plasma channel,

$\boldsymbol{\lambda}$ - mean free path of the particle and the x - coordinate in the direction of motion of charges.

Then the amount of charge absorbed is equal to

$$q_{adsorb} = q_0 - q = q_0\left(1 - \exp\left(-\frac{x}{\lambda}\right)\right) \tag{3}$$

Analogously the equation (2) similar considerations may determine the amount of the initial mass $\boldsymbol{m_0}$ uncharged aerosol particles interacting with the plasma channel corona on the path $\boldsymbol{dx = \vartheta dt}$ direction of flow

$$m = m_0 \exp(-\frac{\vartheta}{\lambda}t) \tag{4a}$$

If in equation (4a) the mean free path of the particle expressed through of the environment interaction parameters we obtain,

$$m = m_0 \exp(-\alpha t) \tag{4b}$$

with $= \frac{\vartheta\, j}{\mu \varepsilon E^2}$, where m_0- initial amount (weight) of the particles, kg; j - ion current density, A / m^2; μ - ion mobility, m^2 / Vs; ϑ is the velocity of the flow of particles, m / s; E- electric field, V / m; ε- dielectric constant of medium.

Also under the influence of electrostatic forces, the charged particles are precipitated on the precipitation electrode. Thus, there are two separate processes that affect the amount of charged particles in the active zone of the electrostatic precipitator. Quantity charged particles (without precipitation of the charged particle) equals

$$q_1(t) = q_0\,[1 - exp(-\alpha t)] \tag{5}$$

The rate of formation of charged particles obtained from the equation (5):

$$\vartheta_{\mathrm{chg}}(\mathrm{t}) = \frac{\mathrm{dq_1(t)}}{\mathrm{dt}} = q_0 \alpha exp(-\alpha t) \tag{6}$$

The rate of deposition of charged particles distributed uniformly in the space between the discharge and collecting electrodes can be defined as:

$$\vartheta_p = m_{chg}\frac{\vartheta_1}{d} = m_{chg}\beta \tag{7}$$

with $\beta = \frac{4\pi\varepsilon E^2 r}{6\eta d}$

Wherein in the formula (7) m_{chg} - amount of the charged particles in the interelectrode space, kg; ϑ_1 - velocity of charged particles toward to the collecting electrode m / s; d- spacing between the electrodes, m and η - dynamic viscosity of the gas, $(N\ s)\ /\ m^2$.

The rate of change amounts of the charged particles in the precipitation space can be defined follows:

$$\frac{dm_{chg}}{dt} = \vartheta_{chg}(t) - \vartheta_p(t) \tag{8}$$

Integrating this equation with zero initial conditions, taking into account the expressions (6) and (7) we obtain the equation which determines amount of charged particles located in the studied space:

$$m_{chg} = \frac{m_0\alpha}{\beta-\alpha}[exp(-\alpha\, t) - \ exp(-\beta t)] \tag{9}$$

At the same time the rate of change in the number of particles deposited on the collecting electrode will be equal:

$$\frac{dm_p}{dt} = m_{chg}\beta \qquad (10)$$

Solving this equation by using the expression (9) with the initial conditions $m_p(t)_{|t=0} = 0$, we obtain for the time t the total number of precipitated particles:

$$m_p(t) = \frac{\alpha\beta}{\beta-\alpha} m_0 \left[\frac{1}{\alpha}\left(1 - exp(-\alpha t)\right) - \frac{1}{\beta}\left(1 - exp(-\beta t)\right)\right] \qquad (11)$$

4. Results and discussions

For the analysis of expression (4b), depending on the parameters included in the formula in Figure 1 plotted quantity change of charged particles. The amounts of charged particles in considered space as a function of time for different values of the ion current density is shown in Figure 2

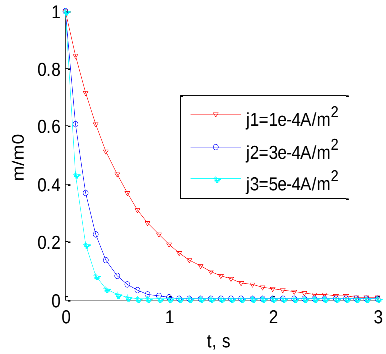

Figure 1. Changes in amount of charged particles as a function of the active zone corona for different values of ion current density

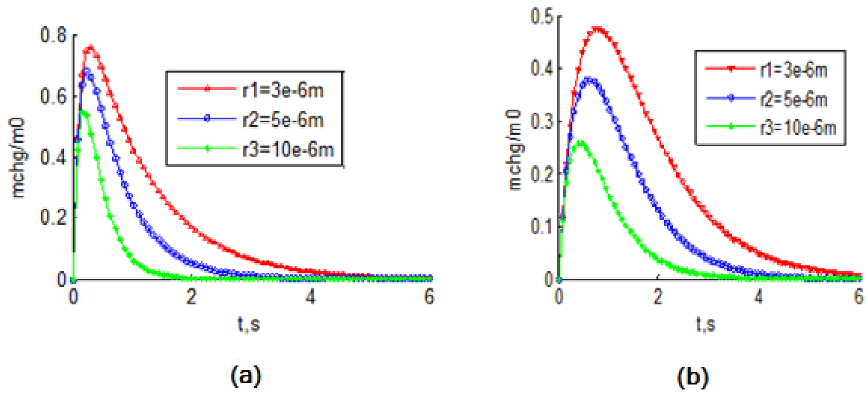

Figure 2. The amount of charged particles located in the studied space, respectively. (a)- at a current density $j = 10^{-4} A/m^2$ and (b)- at a current density $j = 5.10^{-4} A/m^2$

From the expression (11) is easy to determine the coefficient of performance-COP is the ratio of the electrostatic precipitator of the deposited amount of the particles to the initial amount of them using:

$$COP = \frac{m_p(t)}{m_0} = \frac{\beta}{\beta-\alpha}\left(1 - exp(-\alpha t)\right) - \frac{\alpha}{\beta-\alpha}\left(1 - exp(-\beta t)\right) \qquad (12)$$

Consider two extreme cases:

(i) Let $\alpha \to \infty$, then $lim_{\alpha\to\infty} COP = 1 - exp(-\beta t)$. This means that the speed of the charged particles is infinitely large and the produced particles in the corona instantaneously deposited on the precipitation electrode

(ii) Let $\beta \to \infty$, then $lim_{\beta\to\infty} COP = 1 - exp(-\alpha t)$.This means that the particles trapped in the corona charging immediately. These results are shown in Figure 3.

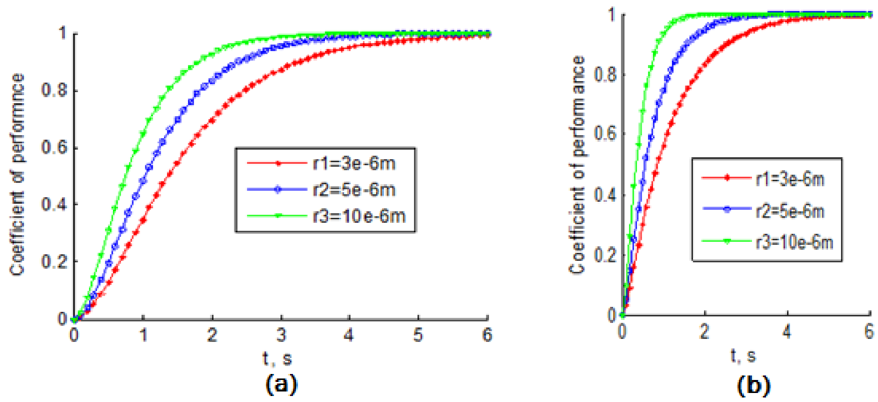

Figure 3. The dependence of the coefficient of performance of the active zone of corona discharge, respectively (a)- at a current density $j = \frac{10^{-4} A}{m^2}$ and (b)- at a current density $j = \frac{5.10^{-4} A}{m^2}$

The analysis of the results shows that with increasing the radius and the ion current density increases the coefficient of performance.

5. Conclusions

We developed the modified equation charging and deposition of aerosol particles in a strong electric field and implemented numerical solution for the charging efficiency of the particles in the corona discharge, depending on the composition of the dispersed particles and the electrical parameters of the discharge.

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