ABSTRACT: Paper deals with dynamics of formation of an electric field of an artificially charged water aerosol cloud. A model of the formation dynamics of artificially charged aerosol clouds created by a charged aerosol generator of a condensate type and a method of calculation of the electric field near boundaries and inside the forming charged part of the cloud are presented. According to calculations, some seconds after the charging beginning are required to create the fully developed charged aerosol cloud. Rise of the electric field strength near the cloud passes two stages: (1) rapid increase up to some kV/cm during some hundreds of ms; (2) relatively slow further growth up to a steady value during some seconds. At the same times, the electric field strength on the boundaries of forming charged aerosol parts of cloud could exceed 10-15 kV/cm during some tens of ms.

INTRODUCTION

Application of the artificially charged aerosol flows for discharge studying can allow us to understand the peculiarities of the discharge appearance and development inside the thunderstorm clouds and beneath them. To create the artificially charged aerosol clouds capable to induced the spark discharges near them the turbulent aerosol jets are used [Vereshchagin et al., 1990]. Method of an electric field calculation of the fully developed charged aerosol turbulent flows has been proposed in [Temnikov and Orlov, 1996].

However, it is often interesting the dynamic formation of the electric field inside such cloud and in a space near its boundaries in order to connect the space-temporal characteristics of the discharge phenomena with an electric field changing in a place of their appearance and along their trajectories. Moreover, it is very interesting to determine the value minimal electric field and its distribution in a forming charge cloud that induce the discharge phenomena of different forms. It is necessary to determine the time gap from the jet charging beginning that is required for the inducing in any point of space the electric field strength from the charged part of the flow sufficient for the discharge phenomena appearance.

Such task is much more complicated than the task of electric field determination of the fully developed charged aerosol jets because the charged turbulent jet formation computation is non stationary case. We have to take into account that the charged part boundaries and the space charged distribution are changed with time.

A model of the formation dynamics of artificially charged aerosol clouds created by a charged aerosol generator of a condensate type and a method of calculation of the electric field near boundaries and inside the forming charged part of the cloud are presented.

MODEL OF THE FORMATION DYNAMICS OF ARTIFICIALLY CHARGED AEROSOL CLOUD

Because of the jet charge is concentrated on aerosol particles, flow can be described with the “big particle” model [Ilyin, 1985]. The last allows us to take into account the action of hydro-dynamical forces of the turbulent flow on the particles of charged aerosol. It also takes into account the action of electrical forces of the forming charged part of aerosol cloud itself. Fluctuations occurring in the turbulent aerosol flow can be taken into account by approximation characteristics [Abramovich, 1984 and 1991]. And the mean trajectories of additive particles that specify the behaviour of charged aerosol can be found. So, in that paper the self-coordinated task of the charged aerosol particles motion in high-speed gas-dynamical turbulent flow and in the electric field created by the charged part of jet with continuously changed boundaries and charge density distributions is solved.

The process of the non-charged aerosol jet propagation in time was quite detail considered in [Abramovich, 1991] where the turbulent jet boundary contours under its development in time were obtained. The auto model profiles of velocities and additives concentrations in the jet were used. However, it is impossible to use this method for the self-coordinated task solving of the charged parts formation dynamics of jet because the location and the distribution of space charge and the force action on aerosol particles are changed with jet charged part development. Different approach in the formation dynamics task solving of charged part of axisymmetrical jet was considered [Vereshchagin et al.,1997]. There the model of “big particles” was used. It was supposed that charge in jet is transported with the charged aerosol drops, and the charged aerosol particles move under the influence acting on them forces. Motion equation of the charged particle was written the following:

\[ m \frac{dV}{dt} = \sum F \]  (1)
where $m$ - mass of the aerosol particle; $V$ - its velocity vector; $\Sigma F$ - sum of the forces acting on the particle.

In gas dynamical turbulent jet the forces acting on the charged spherical aerosol particles are:

a) the Stock’s force of flow resistance $F_S$:

$$F_S = -6 \pi \mu K_h a \cdot (V - U)$$  \hspace{1cm} (2)

b) the electric force $F_E$:

$$F_E = q \cdot E$$  \hspace{1cm} (3)

where $a$, $q$ - the radius and the charge of the drop; $U$ - the gas dynamical flow velocity; $\mu$ - the viscosity coefficient for air; $E$ - the electric field in the point where drop is situated in that moment; $K_h$ - Koeningam corrector factor (was used for particles less than the micron dimension).

The force of gravity acting on the aerosol particle doesn’t take into account because it is very less in comparison with others for the aerosol particles less than 1 $\mu$m.

Equation of motion (1) has been solved analytically on every time step. That has allowed to coordinate the solution with the electric field calculation equation from the space charge of the forming charged part of jet.

Equation of motion of the aerosol particle in the axial and radial directions had the following form:

\[
\frac{d^2 z}{dt^2} = \frac{\sum F_z}{m} = w_z \hspace{1cm} \frac{d^2 x}{dt^2} = \frac{\sum F_x}{m} = w_x
\]

\[
\frac{d z}{dt} = v_{z0} + \frac{d^2 z}{dt^2} \Delta t = v_z \hspace{1cm} \frac{d x}{dt} = v_{x0} + \frac{d^2 x}{dt^2} \Delta t = v_x
\]

\[
z = z_0 + v_{z0} \cdot \Delta t + 0,5 \cdot w_z \cdot (\Delta t)^2 \hspace{1cm} x = x_0 + v_{x0} \cdot \Delta t + 0,5 \cdot w_x \cdot (\Delta t)^2
\]

where $v_{z0}$, $v_{x0}$ - the aerosol particle velocity on the previous time step into the axial and radial directions; $w_z$, $w_x$ - the aerosol particle accelerations on that time step; $\Sigma F_z$, $\Sigma F_x$ - the acting in both directions forces; $\Delta t$ - time step.

**DYNAMICS OF ELECTRIC FIELD FORMATION INSIDE THE CHARGED AEROSOL CLOUD AND NEAR ITS BOUNDARIES**

Dynamic of formation of the charged parts inside the turbulent aerosol flow is shown in Fig. 1.
The mean trajectories of the charged particles that are situated on the boundary of the charged turbulent flows was computed for the following parameters of the charged aerosol generator used in experiments [Temnikov and Orlov, 1996; Vereshchagin et al., 1997]: flow velocity in the nozzle section \( u_0 = 400 \text{ m/s} \); the outlet current of generator \( I = 120 \mu\text{A} \); the nozzle diameter \( d_0 = 6 \text{ mm} \); the aerosol particle radius \( a = 0.4 \mu\text{m} \); the charge of aerosol particle \( q = 4 \times 10^{-17} \text{ C} \); the average space charge density in the beginning cross-section of the main part of jet \( \rho_m = 2.3 \times 10^{-4} \text{ C/m}^3 \); length from the generator screen and the grounded wall 3,3 m; height of the nozzle above the grounded plate 0.8 m; jet axis slope 3°.

As we can see in the figure 1, after the beginning of charged aerosol generator the charged part during first second occupies only approximately a half of the aerosol cloud region.

During first tens of millisecond potential of the cloud rises up to some hundred kV and electric field strength near the nozzle screen increases to 9-10 kV/cm (Fig. 2). At the same time, electric field strength on the grounded plane beneath the aerosol cloud is less than 1 kV/cm. In such situation discharge phenomena could appear before near the nozzle screen.

For a second after the charging beginning potential of the cloud reaches more than five hundreds kV. Electric field strength near the nozzle screen and on the boundary of the charged parts of aerosol flow is 10-12 kV/cm (Fig. 3). And for that time, electric field strength on the grounded plane beneath the aerosol cloud can be more than 5-6 kV/cm. Such condition are favorite for the discharge occurrence as near the aerosol cloud boundaries as on the grounded plane.
Dynamics of the electric field formation in the different points (1 - x = 0 m, z = 1.2 m; 2 - x = 0 m, z = 0.6 m; 3 - x = 0.45 m, z = 1.2 m; 4 - x = 0.45 m, z = 0.6 m; 5 - x = 0.78 m, z = 1.2 m; 6 - x = 0.78 m, z = 0.6 m) of the gap “charged aerosol cloud – grounded plate” is shown in Fig. 4.

![Graph showing electric field strength over time](image)

**CONCLUSION**

Calculations of dynamics of the electric field formation in the gap “charged aerosol cloud – grounded plate” have shown the following. Electric field strength near the nozzle screen quickly (during some tens of milliseconds) reaches 9-12 kV/cm and stays on that level further. Electric field on the grounded plate beneath the aerosol cloud (points 1 and 2 in fig. 4) is formed smoothly and reaches the maximal values during the some seconds after the charging beginning. Dynamic of electric field formation inside the aerosol cloud is more complicated. In dependence on the point location electric field strength could sufficiently quickly rises during a hundred of milliseconds, after that it slows down and then begins slow increases up to maximal value during some seconds (for example, point 5 in fig. 4 that are situated near the jet axis). If the point is situated not far from the aerosol cloud boundary (point 3 in fig. 4), electric field rises there on a sufficiently smooth regime. Thus, we can connect the appearing discharge phenomena with the dynamics of the electric field changing in every point inside the aerosol cloud and near its boundaries.

**REFERENCES**


