The Fast Model for Ionic Wind Simulation

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Abstract

Ionic wind is the gas flow induced by the corona discharge. Ions produced by corona are accelerated by electric field and transfer their momentum to neutral molecules. Considering the system not as the ensemble of molecules but as the continuum we can regard that the volume force pE influence on air. Here p is electric charge volume density and E is electric field intensity. Using ionic wind one can convert electric energy to kinetic energy of air flow almost directly. The typical flow has a form of a strong narrow jet between high voltage electrode (HVE) and grounded electrode (Figure 1). The phenomenon of ionic wind finds applications in electrostatic precipitators and ionizers [1,2].

It is difficult to solve the complete system of PDE (known as "the drift-diffusion model") which describe both the corona discharge and hydrodynamics. In unipolar approximation ("the simple model") we take into consideration volume force of ions only and neglect electrons and the corona sheath structure. In this case solution time step and element size may be much larger than in the drift-diffusion model . It provides the higher computation efficiency. However the boundary condition on HVE is an ODE and should be solved coupled with the PDE in the domain. COMSOL Multiphysics® provides the unique possibility to solve such unusual systems of equations and therefore we chose it to build the simple model realization (Figure 2).

The model of the point-plane electrodes' system was created to compare the results with the more complete drift-diffusion model of ionic wind (Figure 3). It was revealed that the simple model has local distinctions up to 50% of air velocity but only near the HVE where the corona sheath structure influences on the flow properties sufficiently. But distinctions of integral characteristics of the flow between the simple model and the drift-diffusion one are less than 10%. Volt-ampere characteristics was a result of solution in both models and corresponded well with the experiment data. Also the cylinder-plane electrodes system model was built. There are wealthy experimental data about the ionic wind flow in this system [3]. At the same time the parameters of this system is near to parameters of industrial electrostatic precipitators. The comparison of the model data with the experimental data revealed that integral parameters of the flow and the flow pattern are reproduced well (Figure 4). Dependencies of the basic parameters on voltage and electric current are in good correspondence with the experiment. As a result building the simple model in COMSOL Multiphysics® provided saving solution time and model size about 10 times in comparison with the more complete drift-diffusion model which is important for further 3D simulations. The both models are approximately equally close to the experimental

data.

Reference

[1] Concettina Buccella Computation of V-I characteristics in electrostatic precipitators Journal of Electrostatics, Vol. 37, Iss. 4, Pp. 277-291 (1996)

[2] A. Bologa et. al. Novel wet electrostatic precipitator for collection of fine aerosol Journal of Electrostatics, Vol. 67, Iss. 2–3, Pp. 150-153 (2009)

[3] Vereschagin I.P. Corona discharge in the devices of electron-ion technology. Russia, Moscow: Energoatomizdat, 1985. 160 Pp. In Russian.

Figures used in the abstract

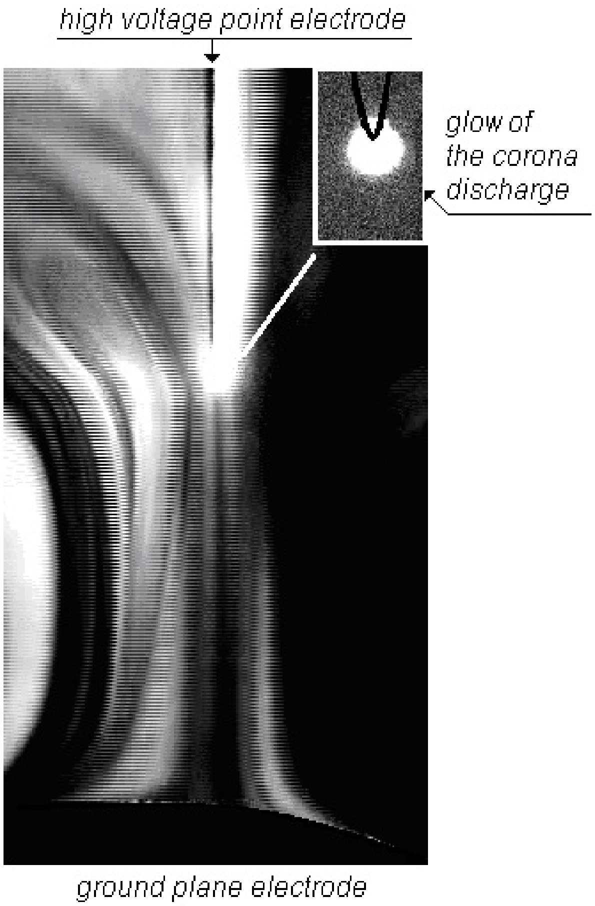

Figure 1: ionic wind flow visualized by brightened smoke. The point-plane electrodes' pair.

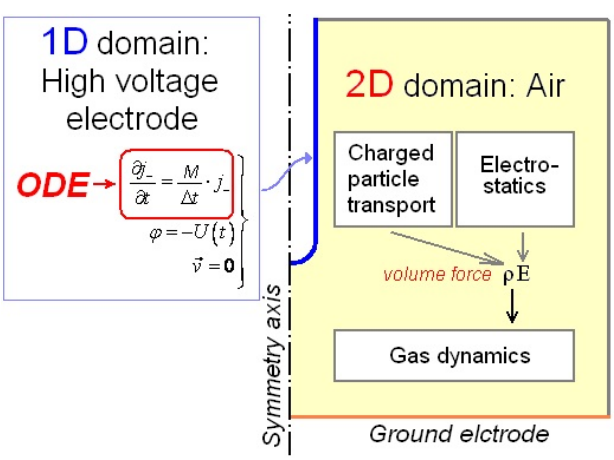

Figure 2: The scheme of the ionic wind model implemented in COMSOL Multiphysics®.

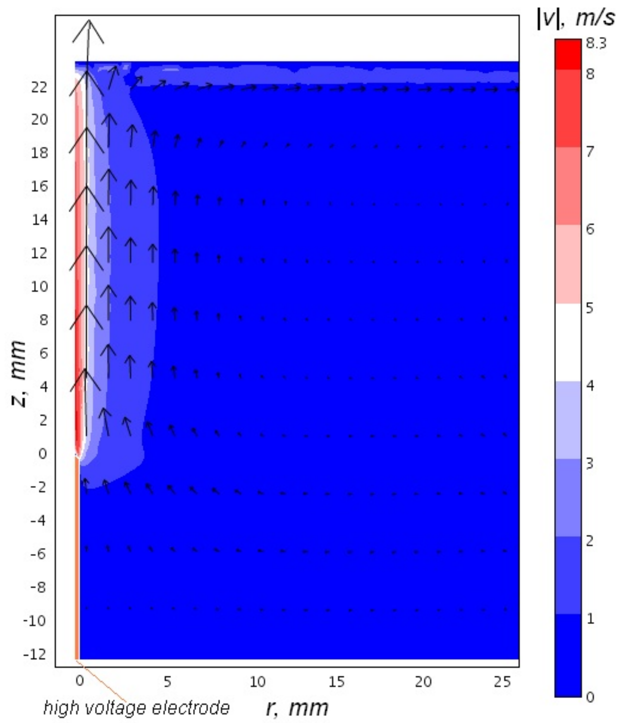

Figure 3: Results of COMSOL Multiphysics® simulation. Air flow of ionic wind in the point-plane electrode system by 11 kV voltage.

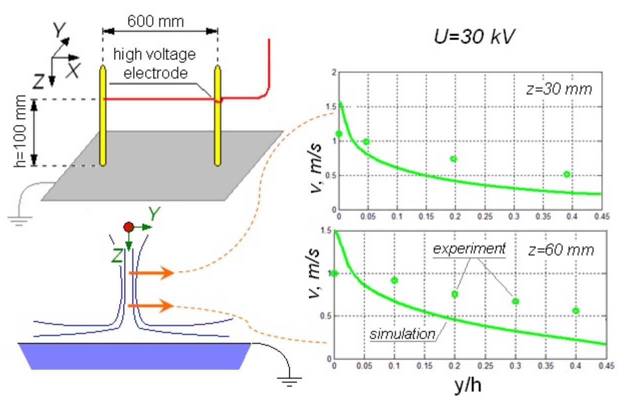

Figure 4: Comparison of air flow profiles in the simple COMSOL Multiphysics® model and in the experiment. The cylinder-plane electrodes' pair.