THE DRIFT-DIFFUSION AND QUASI-NEUTRAL MODELS OF GAS DISCHARGES FOR FLOW CONTROL PROBLEMS

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The analysis of characteristic time scales of elementary physical processes in the glow discharges, that had been considered in the previous lecture, allows to draw a conclusion that approximately in $\tau_p \sim 10^{-4}$ s after electric breakdown the basic relaxation processes in glow discharge plasma are completed. If to take into account, that the characteristic spatial scale of the discharge channel has the value of $L = 1$ cm, it turns out, that at velocities of a gas flow, which are smaller, than $V \le 0.1\left(L/\tau_p\right) \approx 10^3$ cm/s, influence on structure of glow discharge of the physical effects connected with gas motion could be neglected. We shall emphasize, that the given statement is true for the considered discharge parameters. A pressure change in gas-discharge gap, an overheat of gas, an over voltage on discharge gap, et al., will change the specified quantitative adjectives. The given estimations allow to approve, that influence of gas motion on electrodynamic structure of glow discharge cannot be neglected at supersonic and, in particular, at hypersonic velocities of a gas flow. It is obvious, that the fact of high-speed motion of gas should be considered in design-theoretical model of glow discharge also.

1. The drift-diffusion model of glow discharge in the cross flow of neutral gas and in the magnetic field

In the given part the computing model of two-dimensional flat glow discharge in a cross gas flow and in an exterior magnetic field is given. The scheme of the solved problem is shown on fig.1.

The physical model is based on the equations of motion of multi fluid partially ionized gas mixture, which are received from Boltzmann equation with use of instant procedure (Gershman E.N., et al., 1984)

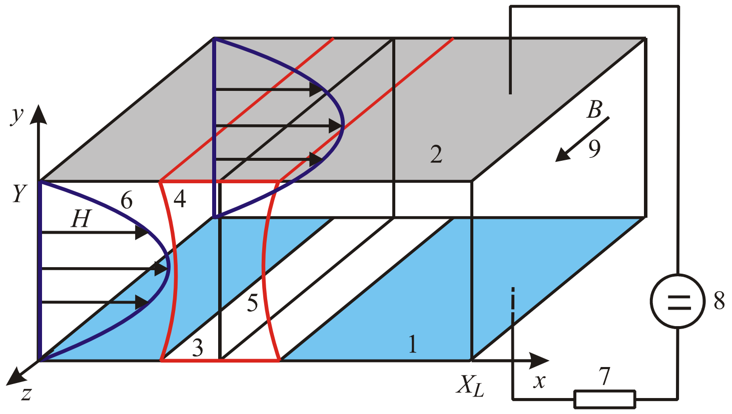

Fig. 1. The scheme of flat glow discharge in a cross gas flow: 1 – cathode; 2 – anode; 3 – cathode layer; 4 – anode layer; 5 – positive column of gas discharge; 6 - gas flow at entry in electrodischarge gap; 7 – active resistance of external electric circuit; 8 – power supply; 9 – external magnetic field

$$n_e m_e \frac{\partial \mathbf{u}_e}{\partial t} + n_e m_e (\mathbf{u}_e \nabla) \mathbf{u}_e = \\ = -\nabla p_e - \boldsymbol{\tau}_e + n_e \mathbf{F}_e - e n_e \left(\mathbf{E} + \frac{1}{c} [\mathbf{u}_e \mathbf{H}] \right) - m_e \nu_{en} n_e (\mathbf{u}_e - \mathbf{u}_n) - m_e \nu_{ei} n_e (\mathbf{u}_e - \mathbf{u}_i) \tag{1}$$

$$n_i m_i \frac{\partial \mathbf{u}_i}{\partial t} + n_i m_i (\mathbf{u}_i \nabla) \mathbf{u}_i = \\ = -\nabla p_i - \boldsymbol{\tau}_i + n_i \mathbf{F}_i + e n_i \left(\mathbf{E} + \frac{1}{c} [\mathbf{u}_i \mathbf{H}] \right) - m_i \nu_{in} n_i (\mathbf{u}_i - \mathbf{u}_e) - m_i \nu_{in} n_i (\mathbf{u}_i - \mathbf{u}_n) \tag{2}$$

where n_e, n_i are the volumetric concentration of electrons and ions; m_e, m_i are the mass of an electron and an ion; $\mathbf{u}_e, \mathbf{u}_i, \mathbf{u}_n$ are the average velocities of electronic and ionic liquids, and also of neutral gas; p_e, p_i are the pressures of electronic and ionic liquids; $\boldsymbol{\tau}_e, \boldsymbol{\tau}_i$ are the components of viscous stress tensor of electronic and ionic liquids; $\mathbf{F}_e, \mathbf{F}_i$ are the volumetric forces effecting on particles of electron and ion liquids; e is the electron charge; c is the speed of light; $\mathbf{E}, \mathbf{H}$ are the strengths of electric and magnetic fields; ν_{en}, ν_{ei} are the frequencies of collisions of electrons with neutral particles and with ions; ν_{in}, ν_{ie} are the frequencies of collisions of ions with neutral particles and with electrons.

To make a series of the estimations simplifying initial equations (1) and (2), we'll take the following assumptions:

1) $m_e << m_i$;

2) a degree of ionization of gas $\alpha < 10^{-4}$, i.e. concentration of the charged particles, is more than by four order of magnitude lower than concentration of neutral particles $n_e \sim n_i << n_n$;