SIMILARITY PARAMETER OF PROCESSES NEAR THE ELECTRODE

A. I. Morozov and A. P. Shubin

UDC 533.9

The nature of the layers near the electrode, which occur in the case of dissipative flow of plasma in the channel of a powerful flow accelerator with a natural magnetic field, depends basically on the extent of the manifestation of the Hall effect [1, 2]. The nature of the layers near the electrode can be assessed according to the magnitude of the similarity parameter given below.

The extent of the manifestation of the Hall effect can be assessed according to the magnitude of the parameter of exchange ξ [3]. In the case of small ξ ($\xi \to 0$) when the ionic and electron trajectories of the electrodes into the depth of the flow of plasma is subject to the laws of the skin effect. However, where $\xi \gtrsim 1$ the difference in the trajectories is substantial; this leads to the fact that the disturbances are propagated along the electron trajectory from the cathode [1], and an electromagnetic layer is formed near the anode. It can be said that the Hall effect, i.e., the transfer along the electrode trajectories, makes the layer near the cathode wider, and the layer near the anode narrower, so that in the case of a strongly expressed Hall effect, the layer near the cathode is distributed over the whole flow and only the layer near the anode remains.

The thickness of the skin layer δ_S is determined by the diffusion of plasma in the magnetic field and according to the order of magnitude equal to

$$\delta_s \sim L\left(\frac{c_T^2}{v_M^2 \lambda L R_m}\right)^{1/2} \quad \left(R_m = \frac{v_M L}{\nu_m}\right)$$

Here L is the length of the accelerator, R_m is the magnetic Reynolds number ($R_m \gg 1$), v_M is the maximum speed of outflow, c_T is the speed of sound at the inlet to the channel, $\lambda = l^{-1}$, where l is the length of the wave of the disturbance in the longitudinal direction. When $l \lesssim L$, then $\lambda L \gtrsim 1$.

The thickness of the Hall layer δ_H is equal to the thickness of the layer of screening of the plasma by the longitudinal Hall electric current, which is pressed by the accelerating plasma to the cathode. For the channel of the slowly varying cross section in the system of acceleration "electron wind" we have [2]

$$\frac{j_x}{\sigma} = \frac{M}{e\rho}\frac{dP(x)}{dx} = -\frac{M}{e} v \frac{\partial v}{\partial x}$$

where the x axis is directed along the channel.

On the other hand,

$$j_x = \frac{c}{4\pi}\frac{\partial B}{\partial y} = \frac{c}{B}\frac{\partial}{\partial y}\frac{B^2}{8\pi} = -\frac{c}{B}\frac{\partial p}{\partial y} = -\frac{c c_T^2}{B}\frac{\partial \rho}{\partial y}$$

Hence,

$$\frac{M}{e}\frac{v_M^2}{L} \sim \frac{c c_T^2}{B\sigma}\frac{\rho}{\delta_H}$$

Moscow. Translated from Zhurnal Prikladnoi Mekhaniki i Tekhnicheskoi Fiziki, No. 1, pp. 117-118, January-February, 1972. Original article submitted May 13, 1971.

Hence,

$$\delta_H \sim L \frac{c_T^2}{v_M^2} \frac{1}{\omega\tau} \quad \left(\omega\tau = \frac{M\sigma B}{e\rho c}\right)$$

where $\omega\tau$ is the Hall parameter in the inlet to the channel.

We will introduce the dimensionless relationship

$$\alpha = \frac{\delta_H}{\delta_s} = \frac{1}{\omega\tau} \left(R_m \lambda L \frac{c_T^2}{v_M^2}\right)^{1/2}$$

Taking the above into account, when $\alpha < 1$ the Hall effect prevails over the skin effect; when $\alpha > 1$ the influence of the Hall effect is small. The condition for the appearance of the Hall effect can be written in the form

$$\chi = \frac{R_m}{(\omega\tau)^2} \frac{c_T^2}{v_M^2} < (\lambda L)^{-1}$$

Hence it is seen that the Hall effect is manifested most strongly on long wave disturbances, i.e., when the condition $\chi < 1$ is fulfilled.

The parameter χ is the parameter of similarity of the processes near the electrode. Where $\chi \gg 1$, the influence of the Hall effect is insignificant; i.e., symmetrical skin layers are formed near the electrode. If $\chi \ll 1$, then the influence of the Hall effect becomes significant.

LITERATURE CITED

1. A. I. Morozov and A. P. Shubin, "The flow of plasma between electrodes of weak longitudinal conductivity," Teplofiz. Vys. Temp., 3, No. 6 (1965).
2. A. I. Morozov and A. P. Shubin, "The theory of plane flows of a good conducting plasma in a channel," Zh. Prikl. Mekhan. i Tekh. Fiz., No. 4 (1970).
3. A. I. Morozov and L. S. Solov'ev, "A similarity parameter in the theory of plasma flows," Dokl. Akad. Nauk SSSR, 164, No. 1 (1965).