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AUTHORS: Strakhovich, K. I., Sokovishin, Yu. A.

TITLE: Discharge of a laminar jet of conductive gas into a magnetic field

PERIODICAL: Inzhenerno-fizicheskiy zhurnal, v. 5, no. 10, 1962, 65 - 69

TEXT: This is studied by the methods of laminar boundary layers and jet streams. The gas jet is assumed to be discharged from a narrow slit of infinite length and to flow into the same gas kept at a constant pressure.  $\gamma$ ,  $\sigma$  and  $\mu$  are constant. Thermal effects and gas ionization are neglected. The equation of motion

$$\left. \begin{aligned} \bar{u} \frac{\partial \bar{u}}{\partial x} + \bar{v} \frac{\partial \bar{u}}{\partial y} &= \frac{\nu}{u_0 l} \frac{\partial^2 \bar{u}}{\partial y^2} - \frac{\sigma \mu^2}{\rho u_0} l H_0^2 \bar{u} \bar{H}^2 \\ \frac{\partial \bar{u}}{\partial x} + \frac{\partial \bar{v}}{\partial y} &= 0, \quad \frac{\partial \bar{H}_x}{\partial x} + \frac{\partial \bar{H}_y}{\partial y} = 0 \\ \frac{\partial \bar{H}_x}{\partial y} &= \frac{d\bar{H}}{dx} - \sigma \mu u_0 l \bar{u} \bar{H} \end{aligned} \right\} (3)$$

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of the gas in the reduced variables

$$\bar{x} = \frac{x}{l}, \quad \bar{u} = \frac{u}{u_0}, \quad \bar{y} = \frac{y}{l}, \quad \bar{v} = \frac{v}{u_0},$$

$$\bar{H} = \frac{H}{H_0}, \quad \bar{H}_y = \frac{H_y}{H_0}, \quad \bar{H}_x = \frac{H_x}{H_0}$$

is transformed to the system

$$\frac{\partial \bar{\psi}}{\partial y} \frac{\partial^2 \bar{\psi}}{\partial x \partial y} - \frac{\partial \bar{\psi}}{\partial x} \frac{\partial^2 \bar{\psi}}{\partial y^2} = \frac{1}{\text{Re}} \frac{\partial^3 \bar{\psi}}{\partial y^3} - N_0 \bar{H}^2 \frac{\partial \bar{\psi}}{\partial y} \quad (6),$$

$$\frac{\partial \bar{H}_x}{\partial y} = \frac{d\bar{H}}{dx} - \text{Re}_\mu \bar{H} \frac{\partial \bar{\psi}}{\partial y}, \quad (7)$$

by introducing the dimensionless parameters

$$\text{Re} = \frac{u_0 l}{\nu}, \quad \text{Re}_\mu = \sigma \mu u_0 l, \quad N_0 = \frac{\sigma \mu^2}{\rho u_0} l H_0^2 \quad (4)$$

and the dimensionless stream function  $\bar{\psi}$ . This system is solved with the following boundary conditions: (a) on the jet axis ( $\bar{y} = 0$ ),  $\bar{v} = 0$ ,

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$\partial \bar{u} / \partial \bar{y} = 0$ ,  $\bar{H}_x = 0$ ; (b) if  $\bar{y} \rightarrow \infty$ ,  $\bar{u} = 0$ ; (c) at a great distance from the slit  $\bar{H}_y = \bar{H}_z = 0$ . From this system the principle of linear momentum  $\bar{H}^2 x^{2+q} p = \frac{ab}{N_0 f(\infty)} \int_0^\infty \{f'(\eta)\}^2 d\eta = \text{const}$  is derived. This equation is possible only if  $\bar{H} = x^n$ , where  $n = (p-q-1)/2$ .  $a$ ,  $b$ ,  $p$  and  $q$  are constants. On the condition that  $p = 0$ ,  $q = 1$ , and  $n = -1$  the solutions

$$\bar{u} = \frac{3}{2} \frac{N_0}{x} \left(1 - \text{th}^2 \frac{\eta}{2}\right) \quad (17),$$

$$\bar{v} = \frac{3}{2} \sqrt{\frac{N_0}{\text{Re}}} \frac{\eta}{x} \left(1 - \text{th}^2 \frac{\eta}{2}\right) \quad (18)$$

are obtained for the velocity components,

$$\bar{H}_y = \frac{1}{x} - \frac{\eta}{x} \frac{1}{N_0 \text{Re}} \left(\eta + 3 \text{Re}_* N_0 \text{th} \frac{\eta}{2}\right), \quad (22) \text{ and}$$

$$\bar{H}_z = -\frac{1}{x} \frac{1}{\sqrt{N_0 \text{Re}}} \left(\eta + 3 \text{Re}_* N_0 \text{th} \frac{\eta}{2}\right) \quad (23)$$

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for the components of the magnetic field and

$$Q = 2\rho \int_0^\infty u dy = 6\mu H_0 \sqrt{\rho \nu \sigma} \quad (19)$$

for the amount of fluid discharged per unit of time. At other values of  $n$  the equations of magnetohydrodynamics are not fulfilled.

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