HYDRODYNAMIC STRUCTURE AND HEAT TRANSFER IN THE INITIAL REGION OF AN ARGON PLASMA JET

I. Dundr and Ya. Kuchera

UDC 533.9.01:536.24

The relationship between the hydrodynamic structure of a turbulent argon plasma jet and the intensity of heat transfer between the flow and the wall normal to it is analyzed.

The initial segment (the potential-core region of the jet) of a plasma jet is the operating region in many industrial applications of plasma and, therefore, considerable attention has been devoted to its investigation. The hydrodynamics and the thermal structure of the jet and also the intensity of heat transfer between plasma jet and the wall normal to it were investigated in the course of a complex investigation of free plasma jets at the Institute of Thermal Mechanics of the Academy of Sciences of the Czechoslovak SSR using a segmented plasmotron of type 100 V [3] with different geometrical dimensions of the discharge chamber with tangential as well as axial supply of argon [4]. The hydrodynamic structure of the jet with rotational arc stabilization gets complicated. In certain operating regimes there is tangential component of the flow at the exit from the plasmotron [5]; therefore the effect of the hydrodynamic structure on the intensity of heat transfer \( q \) was investigated on the variant of the plasmotron with axial feed. The anode diameter \( D_a \) was 8 mm, the distance between the electrodes was 127 mm, the diameter of the discharge chamber was 15 mm, and the argon was fed along the front part of the cathode. The ranges of the operating parameters of the plasmotron were: \( I = 50-180 \, \text{A}, \, U = 78-144 \, \text{V}, \, G_A = 0.3-3.8 \, \text{g} \cdot \text{sec}^{-1} \).

Characteristics of the Structure of the Plasma Jet

The determination of the plasma-jet structure is made difficult by the fact that the basic hydrodynamic and thermal quantities, i.e., the velocity, the dynamic pressure, and the temperature in the exit section of the plasmotron nozzle, depend on the operating parameters of the plasmotron in different ways [6].

The magnitude of the maximum dynamic pressure at the exit aperture of the plasmotron with a relatively long discharge chamber \( (L' > 8) \) depends on \( h_s C_A^3 \), while in the range 0-3000...
Fig. 1. The ratio of maximum and mean dynamic pressures in a plasma jet [1] $P_{dm}/P_{ds}$; 2) $T_m/T_s$]?

Fig. 2. The dependence $h_s = f(h_s G_A^2)$ for a plasmotron with axial argon supply.

It is given by the expression* [7]

$$P_{dm} = \left( \frac{0.68 \times 10^{-3}}{D_a} \right) (h_s G_A^2)^{0.44}$$

On the other hand, the maximum temperature can be regarded as constant in the first approximation. In all measurements (different dimensions of the discharge chamber, different methods of gas feed) the temperature was varied in the range $T_m = 10,500 (\pm 14\%)$. The ratio of the maximum and mean values of the dynamic pressure, which qualitatively characterizes the shape of the pressure profile according to Fig. 1, depends only on the mean enthalpy of plasma $h_s$ [8]. The ratio $T_m/T_s$ also has a similar form of the dependence on $h_s$. A comparison of the radial profiles of the temperature and the dynamic pressure shows that the temperature profile for $h_s = \text{const}$ will be more flat than the pressure profile. On decreasing the flow rate of the gas (Fig. 2) for $h_s = \text{const}$ the ratios $T_m/T_s$ and $P_{dm}/P_{ds}$ remain constant. On changing $G_A$ the magnitude of the pressure $P_{dm}$ changes appreciably (approximately in ratios corresponding to the magnitude of $h_s G_A^2$). On the basis of Fig. 1 for a plasmotron with axial argon feed the temperature $T_m$ can be expressed by the equation

$$T_m = 3.83 h_s^{0.77} \frac{T_s}{h_s^{0.77}} \quad \text{for} \quad h_s \lesssim 5 \text{kJ \cdot g}^{-1}, T_M = 1.05T_s \approx \text{approximately}.$$

The investigations carried out here show that for $h_s = \text{const}$ the maximum temperature and the radial temperature profile do not change, while the maximum dynamic pressure changes significantly. On the contrary, for regimes $h_s G_A^2 = \text{const}$ the radial temperature profile will

*For a plasmotron with a sharp discharge chamber the following expression holds:

$$P_{dm} = \left( \frac{0.38 \times 10^{-3}}{D_a} \right) (h_s G_A)^{0.9}$$