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IMPROVEMENT OF THE CHARACTERISTICS OF A PLASMA TORCH AT LOW GAS FLOW RATE

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It is shown that the gas dynamics of a plasma torch and its characteristics depend on the configuration of the discharge chamber. Tapered boring at the cylindrical anode inlet (10^0 over a length of 11 mm) makes it possible to increase the arc voltage, torch efficiency, and enthalpy of the plasma jet at low gas flow rates. At high gas flow rates, the above parameters are higher in a torch where the anode does not have tapered boring. This is explained by turbulization of the heated gas.

Plasma torches have found wide use in industry for various purposes, e.g., plasma cutting, welding and melting of metals, plasma spraying of various coatings onto a surface, plasma reduction processes, chemical reactions of organic and inorganic materials, plasma treatment of materials, etc. Knowledge of the processes in discharge chambers of torches has a large bearing on their design.

The present work is devoted to investigating the influence of boring at the cylindrical channel inlet of the output electrode of a plasma torch on its electrical and thermal characteristics. At low gas flow rates, tapered boring of the anode results in a substantial increase in the enthalpy and efficiency of a plasma torch. In the investigations, use was made of a torch with a nonpenetrating arc, self-stabilizing over its length, blown by an eddy air flow in a cylindrical copper anode of length 12 cm and inner diameter 9.52 mm. A zirconium rod cathode was used. An eddy flow of heavy air, stabilizing the arc, was brought through a vortex gas-supply chamber. To generalize the characteristics of the plasma torch, we used similarity theory. The arc voltage and the torch efficiency were considered to be functions of the measured current and gas flow rate. Heat losses in the electrodes were calculated from the measured flow rates and temperature drops of cooling water.

In the experiments, we used two identical torches but in one of them an angle of 10^0 was bored at the inlet of the cylindrical anode channel over a length of 11 mm. In the both cases the simple expressions

$$U = AI^mG^n; \quad (1 - \eta)/\eta = BI^pG^q .$$

gave a good fit with the experimental data.

Figure 1 represents a comparison of the experimental voltage-current characteristics of both plasma torches. The points of intersection of the curves at equal gas flow rates are connected by line AB. Differences in the efficiencies of these plasma torches for the three current values 60 (1), 100 (2), and 140 A (3) as a function of the gas flow rate are shown in Fig. 2a. It may be inferred that the torch with a taper angle at the anode inlet possesses a higher efficiency. However, as the gas flow rate increases, the increment in the efficiency decreases. Differences in enthalpies at the same current values are shown in Fig. 2b. Here, it is also seen that at low gas flow rates the angle at the anode inlet makes it possible to increase the enthalpy of a plasma jet. Based on the results obtained, we may conclude that at low gas flow rates owing to the angle at the inlet of the anode channel the improved configuration of the boundary layer provides an increase in the arc column length. The arc voltage, torch efficiency, and enthalpy of the plasma also increase. At elevated gas flow rates, the increase in the voltage in the torch without an angle at the anode inlet may be attributed to the enhancement of arc cooling due to gas flow turbulization [1]. At a higher level of turbulence, the increment in the jet enthalpy and the torch efficiency decrease as well. The

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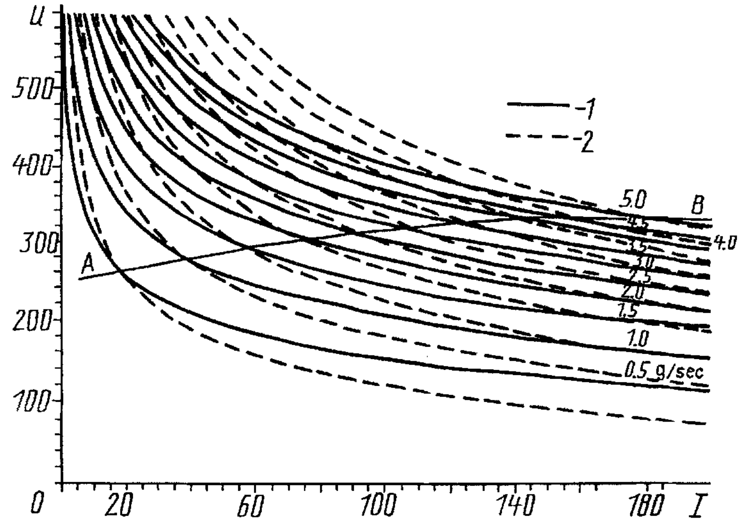

Fig. 1. Voltage-current characteristics of plasma torches at different gas flow rates: 1) with an angle of tapered boring; 2) without an angle of tapered boring. U, V; I,

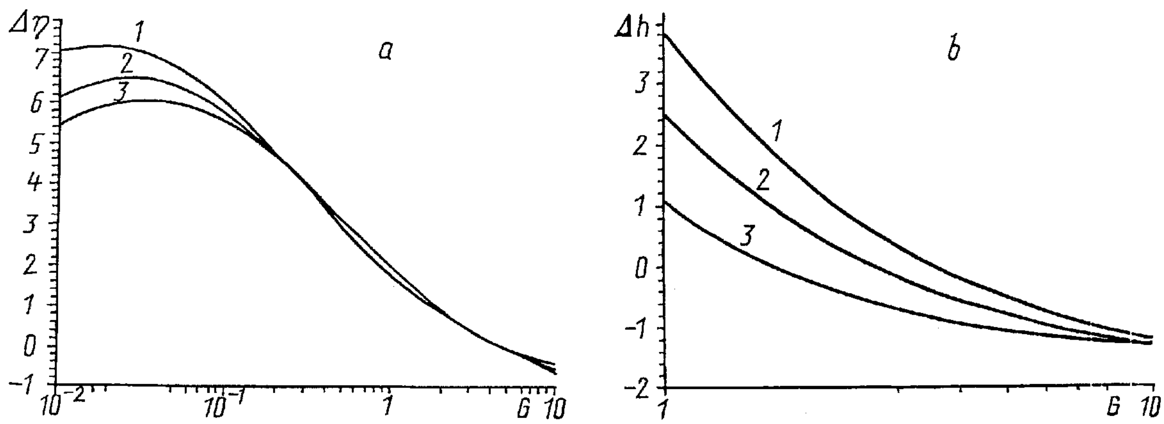

Fig. 2. Increment of the torch efficiency (%) (a) and the enthalpy in the torch (%) (b) with an angle of tapered boring as compared to the torch without it: 1) 140; 2) 100; 3) 60 A. G, g/sec.

fact that the difference in the enthalpy and the efficiency depends much more on the gas flow rate than on the current strength allows us to make a judgment about the hydrodynamic nature of the discussed effect. The author thanks A. A. B. Prado and J. B. Pinheiro from the laboratory of the physics and technology of plasma of the Instituto de Fisica at UNICAMP (the State University of Campinas, Brazil) for technical help in the work. The author would also like to express his gratitude to the Brazilian funds for research promotion CNPq, FAPESP, and FINEP as well as FAEP/UNICAMP for financial support of this work.

NOTATION

U, voltage; I, current; Q, gas flow rate; η, efficiency of plasma generation; A, B, coefficients; m, n, p, q, exponents.

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