acta phys. slov. 35 (1985), No. 2

PREDICTION OF THE OPERATING CONDITIONS FOR HYDROGEN D. C. PLASMATRONS[1]

W. W. PŁOTCZYK,[2] Warsaw

The generalized current-voltage characteristic and energy loss on the cathode and anode and have been established experimentally with arc power 10—43 kW. Next, methods of prediction of the arc voltage and the plasmatron heat efficiency have been elaborated.

О ПРОГНОЗИРОВАНИИ РЕЖИМА РАБОТЫ ПЛАЗМОТРОНА ПОСТОЯННОГО ТОКА, РАБОТАЮЩЕГО НА ВОДОРОДЕ

На основе экспериментов, проведенных при мощностях электрической дуги в области 10 – 43 кВт, определены ее обобщенная вольтамперная характеристика и энергетические потери на катоде и аноде. Кроме того, предложен метод прогнозирования напряжения дуги и термического КПД плазмотрона.

I. INTRODUCTION

Plasmatron, i.e. a plasma stream generator, is the main part of the chemical plasma reactor [1]. Its other parts are: a reaction chamber and a system for rapid cooling of the reaction products (freezing chamber). The efficiency of a chemical process is substantially affected by the working parameters of the plasmatron [1—4]. For planning the initial conditions of a plasmo-chemical process, prediction of the interelectrode voltage and, as a consequence, the arc power and thermal efficiency of the plasmatron are necessary [2, 4].

II. APPARATUS AND METHODS

The experiments were made by using an apparatus consisting of a chemical plasma reactor (Fig. 1) and a measuring system for performing the material and

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[1] Contribution presented at the 5th Symposium on Elementary Processes and Chemical Reactions in Low Temperature Plasma. ŠTIAVNICKÉ BANE, May 21—25, 1984.

[2] Department of Chemistry, Warsaw University, Pasteura 1, 02 093 WARSAW, Poland.

energy balance of the process [1]. The essential part of the reactor is a plasmatron PL-100 with a tungsten cathode and copper anode in the form of a nozzle. Outside the plasmatron a solenoid, producing the magnetic field which stabilizes arc discharges, is placed.

In the present paper we used apart from our own results also the results of papers published earlier [4—6].

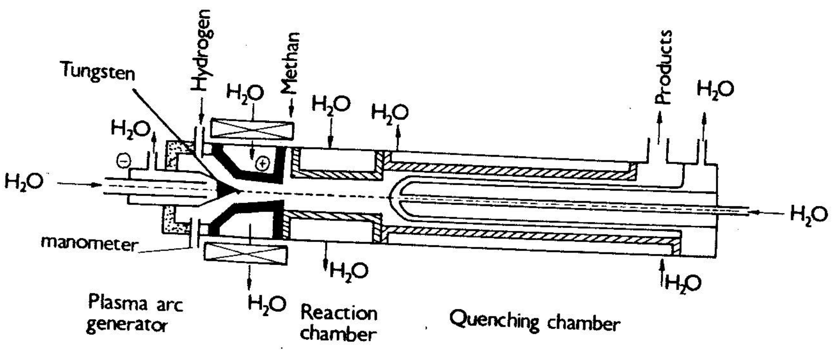

Fig. 1. Diagram of the chemical plasma reactor.

The following ranges in the operating parameters of the plasmatron were obtained in the experiments: power 10—43 kW, hydrogen volume flux 1.9—8.05 m³/h, arc current $I = 95$—350 A, magnetic field intensity $H_m = 22$—90 kA/m, interelectrode distance $l_{ie} = 2$—12 mm, anode length $l_a =$ 18—70 mm, anode diameter $d = 4.5$—13.5 mm and interelectrode pressure $p =$ 0.1—0.17 MPa.

For approximation of experimental dependences the Brandon method of multiple correlation [7] and the method of least squares was used.

III. RESULTS AND DISCUSSION

As mentioned above, a very important parameter of the plasmatron work, besides the interelectrode voltage, is its thermal efficiency η. It characterizes the efficiency of exchange between the arc energy E and the energy of the flowing out plasma stream E_{pj}. η is calculated from the formula

$$\eta = \frac{E_{pj}}{E} = \frac{E - Q_{kt} - Q_a}{E} = \frac{3.6\,UIt \times 10^{-3} - Q_{kt} - Q_a}{E} \tag{1}$$

where: Q_{kt}, Q_a are the energies caused by the water cooling the cathode and anode, respectively [MJ], U — interelectrode voltage [V], I — arc current intensity [A], t — time, equal to 1 h.

The relation between the interelectrode voltage and the working parameters of the plasmatron is approximated by the following relation:

$$U = 462.4\,(I^2/Vd)^{-0.69}(V/d)^{-0.51}(pd)^{0.28}(l_{ie}/d)^{0.01} + \\ \times (H_m d/I)^{0.01}(I/d). \tag{2}$$

The comparison between calculated and experimental values of the interelectrode voltage is given in Fig. 2. The plasmatron efficiency was predicted on the basis of formula (1). This required the energy lost caused by the water cooling the electrodes to be expressed as a function of the operating parameters of the plasmatron. The above-mentioned values were approximated by the following formulas

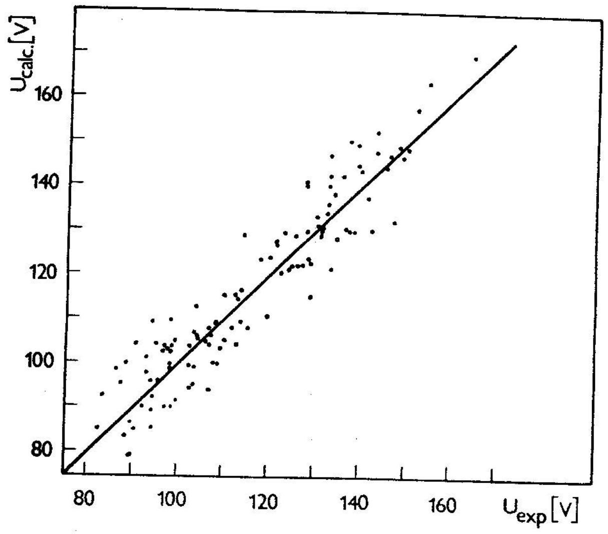

Fig. 2. Comparison between the calculated ($U_{calc.}$) and the experimental ($U_{exp.}$) values of interelectrode voltage.

$$Q_{kt} = 10.681 - 2.413 \times 10^{-3} I + 2.395 \ln I + 0.0385\,V + \\ + 2.054 \times 10^{-3} H_m + 19.429\,l_{ie} + 6.545\,p, \tag{3}$$

$$Q_a = 3.69(-2.055 + 4.155\,l_a)(0.619 + 0.04\,d)(0.221 + \\ + 0.0035\,I)(0.878 + 1.704 \times 10^{-5} H_m I)(0.674 + 0.331\,pd) \times \\ \times (1.253 - 0.0592\,V)(1.206 - 0.355\,l_{ie})^{-1}. \tag{4}$$

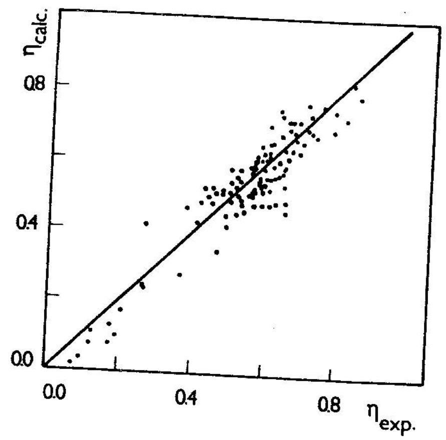

Fig. 3. Comparison between the calculated ($\eta_{calc.}$) and the experimental ($\eta_{exp.}$) values of plasmatron efficiency.

The comparison between the calculations according to formulas (1), (3) and (4) (by using the experimental values of the arc power) and the experimental plasmatron efficiencies is represented in Fig. 3.

Figs. 2 and 3 showed that a satisfactory approximation of experimental data by analytical dependences was obtained. This made it possible to work out formulas predicting with sufficient accuracy the interelectrode voltage and plasmatron thermal efficiency. These formulas seem to be useful in studies of plasmatrons.

ACKNOWLEDGEMENTS

I wish to thank Professor Andrzej Szymański for stimulating discussions and remarks.

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Received June 8th, 1984