PLASMATRON-REACTOR FOR ELECTRIC-ARC HEATING OF HYDROGEN-METHANE MIXTURES

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ABSTRACT

The results of the study of a combined plasmatron-reactor with bilateral plasma jet efflux, cylindrical hollow electrodes and interelectrode insertions of smaller diameter are presented. The plasmatron-reactor is intended for plasmochemical production of acetylene from hydrocarbons and can be also used for other plasmochemical and plasmometallurgical processes.

The plasmatron power ranged from 150 to 1200 kW with arc current between 200 and 900 A and specific real power from 1.2 to 3.5 kW/Nm^3. Natural gas (vol. %) CH_4-90.7; C_2H_6-4.1; C_3H_8-0.9; C_4H_{10}-0.4; O_2-1.6; CO_2-1.7 served as raw material. Commercial hydrogen (vol. %) H_2-97.1; O_2-0.7; N_2-1.7; CH_4-0.5 was used as a heat carrier. Pyrolysis products were quenched with water. The raw material-heat carrier reaction time was measured with reaction chambers of different lengths. Pressure in the reaction zone ranged from 0.105 to 0.125 mPa [1-3].

Generalized current-voltage characteristics of the combined plasmatron-reactor have been obtained for revealing the laws of heat transfer between the electric arc and gas flow. Numerical estimates were used to identify the most important phenomena and to derive the appropriate criteria. Those were studied to generalize the experimental data by analysing scattering in the power-law approximation of the relationships. A variable chemical composition of the mixture heated was allowed for either through the introductions of the volumetric concentration of natural gas into the correlations or through the use of the governing physical properties of a particular mixture calculated earlier [4-5]. The calculations were made separately for ascending and descending branches of the current-voltage characteristics. Thus, for the ascending branch:

$$U/(\sigma_0/\lambda_0 T_0) = 128.16(I^2/\sigma_0 h_0 dZG)^{-0.20} \qquad \delta = 0.127$$

$$U/(\sigma_0/\lambda_0 T_0) = 174.35(I^2/\sigma_{H_2} h_{H_2} dG_{H_2})^{-0.21}\omega^{-0.17} \qquad \delta = 0.126$$

With the increasing number of the criteria, relative scatter decreases:

$$UI(\sigma_0/\lambda_0 T_0) = 12.\text{[illegible]}(I^2/\sigma_0 h_0 d\Sigma G)^{-0.33} \times$$

$$\times\ (I^2/\sigma_0 \lambda_0 T_0 d^2)^{0.24} \qquad \delta = 0.108$$

Power supplied to the arc of the plasmatron-reactor is spent for production of acetylene (43.5%), formation of by-products (1%). Energy for quenching amounts to 43.5%, heat losses in plasmatron--reactor elements are equal to 12%. The energy balance analysis shows that the fraction of power input spent for the desired reaction is much higher than for oxidizing methane pyrolysis when only 30-33% of power input are spent just for the reaction. This points to appropriate mixing of the raw material and heat carrier in the plasmatron. At the same time small losses in its elements point to economic heating of plasma heat carrier inside the interelectrode inserts and support the idea of chemical reactions in electrode cavities.

Heat fluxes to the elements of the combined plasmatron-reactor are given in a criterial form with regard for raw material dilution with hydrogen, energy criterion and conversion into acetylene

$$Q_e/Q_{C_2H_2}\ G_{CH_4}\ \gamma_{C_2H_2} = 2.10^{-3}(\omega K_{en})^{-0.058} \quad .$$

To design the plasmatron as a chemical reactor, the generalized current-voltage characteristic must be presented as:

$$\omega K_{en} = 12.0\eta \frac{h_0}{Q_{C_2H_2}} (h_0 \Sigma G/\lambda_0 T_0 d)^{-0.264} (I^2/\sigma_0 h_0 d\Sigma G)^{0.382}$$

The relationships obtained can be used for complex analysis of the prescribed raw material-acetylene conversion and of heat losses to the elements of the combined plasmatron-reactor.

REFERENCES

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