RESEARCH OF POWER PROCESSES OF HYDROGEN REACTOR ELECTROCHEMICAL GENERATION

Shalimov Yu.V.*, Ostrovskaya E.N.[1], Litvinov Yu.V.[1]
*Voronezh State Technical University, 14, Moscovsky Prospekt, Voronezh, 394026 Russia
[1]FSUE NKTB "Ferrite", 179/4, Moscovsky Prospekt, Voronezh, 394066 Russia

Introduction

At studying thermal losses in electrochemical gas reactors one usually proceeds from a condition of Joule heat scattered in the inter-electrode space being the basic source of thermal losses. As shown by the detailed studying of the thermal mass transportation processes in electrochemical converters, the effects of thermal emission render the basic influence on the distribution behavior of thermal fields in the reactor volume.

Results and discussion

By consideration of the electrochemical cell containing parallel lines of identical electrodes located on the rectangular grid units, it is possible to enter simplifications in connection with the system symmetry. In this case it is enough to consider one line of electrodes. For an electrode with a great *l/d* ratio the current distribution on length is practically homogeneous, except for a small area of regional effects on the end of an electrode.

Schematic distribution of electrodes in a cell is shown in Fig. 1.

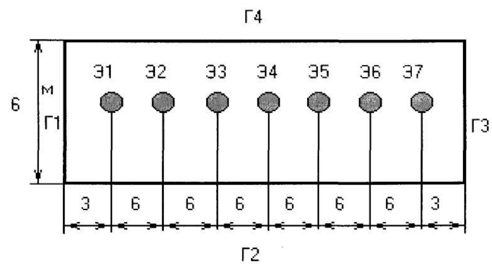

Fig. 1. Geometry of calculated area for the cylindrical electrode system: E - electrode, M - membrane, B_k – borders of area

The initial distribution of the current density is shown in Fig. 2. As seen from the Figure, in this task the first electrode shields all system almost completely.

The secondary distribution obtained by the iterative solution of the set task is resulted in Fig. 3. Here the screening degree of the first electrode in respect to the others is much lower, but only two forward electrodes appear to be practically working. The distribution of electrolyte potential at an electrode and the current density determined on the electrode perimeter have cosine character.

The revealed heterogeneity of the electrodes load perfectly matching the experimental data is caused by use of the circuit with identical potential on all electrodes. In this case the most strongly loaded electrodes are the ones in the center of a cell, i.e., being in the conditions of the worst heat exchange. This effect is also illustrated by the distribution of Joule sources of heat (Fig. 4) which density differs by the calculated area length more than at three orders.

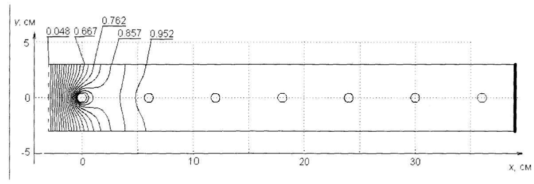

Fig. 2. Initial distribution of dimensionless potential in the cell with cylindrical electrodes

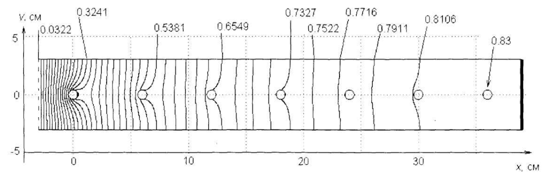

Fig. 3. Secondary distribution of dimensionless potential in the cell with cylindrical electrodes

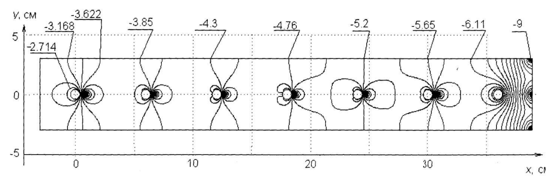

Fig. 4. Distribution of the decimal logarithm of volumetric density of Joule sources of heat

With the purpose of the thermal mode optimization it is expedient to redistribute the load of electrodes by current by establishing various specially selected potentials on the electrodes.

By optimization it is necessary to achieve approximately linear change of the potential gradient. For this purpose it is enough to set distribution of the required current density at the electrodes and by the expression:

$$u_k = \sum_{m=1}^{n} L_{km} \left.\frac{\partial u}{\partial n}\right|_m \qquad (1)$$

with the use of the matrix one obtains the potentials u_k, and by the boundary condition:

$$u = 1 - \frac{1}{\beta} \cdot \mathrm{Arsh}\left(\frac{\lambda}{(1-\theta')} \cdot \frac{\partial u}{\partial n} \right) - \frac{\alpha(\theta)}{\sqrt{\rho}} \cdot \frac{\partial u}{\partial n} \qquad (2)$$

the potentials v_k on the electrodes are obtained.

Here n is the number of electrodes in the system, and the symmetric matrix L_{km} with dimensional length is determined by the system geometry only; β - the parameter of the superficial overstrain "rigidity"; λ - the characteristic length of the current density change at the electrode surface; α - the dimensionless geometrical factor determined in respect to θ shares of the penetrated part of the membrane surface; ρ - the superficial density of gas bubbles.

The distribution of potentials of electrolyte found by (1) and the matrix makes:

(u_k)=(0,409; 1,021; 1,531; 1,939; 2,245; 2,45; 2,251). (3)

Then the boundary condition (2) determines the potentials of electrodes:

(v_k)=(0,892; 1,504; 2,014; 2,422; 2,728; 2,932; 3,034). (4)

Now the check of correctness of the obtained values and the necessary updating can be carried out within the framework of calculation of field model. Thus in the boundary condition (2) on the electrodes instead of the dimensionless potential value of the electrode 1 it is necessary to substitute the obtained numerical values v_k of each electrode from the expression (4).

The distribution of a field of potentials calculated by the potentials (4) is shown in Fig. 5, and the distribution density of Joule sources of heat is shown in Fig. 6. The value obtained in the model is j_0=0,1169, and the values of j_k make:

(j_k)=(0,0409; 0,0402; 0,0395; 0,0397; 0,0395; 0,0395; 0,0395). (5)

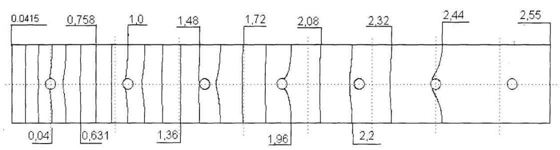

Fig. 5. Secondary distribution of dimensionless potential in the optimized cell

Thus, the exact distribution j_k practically coincides with the one set in the simplified model, the same as the entrance current density j_0. That confirms the reliability and efficiency of the simplified model of optimization. As a result of optimization a considerably more uniform distribution of Joule sources of heat (Fig. 6) is achieved. The calculated heterogeneity of the current density at the electrodes makes j_{min}=0,024, j_{max}=0,062 on the first electrode, and j_{min}=0,038, j_{max}=0,041 on the seventh, accordingly; and all electrodes of the cell are effectively working on the full surface.

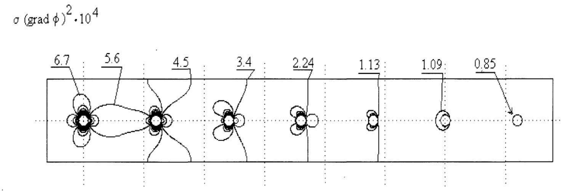

Fig. 6. Distribution of density Joule sources of heat in the optimized cell

The suggested model allows specification of results of the thermal sources localization in the reactor and definition on the basis of real distribution of the direction of thermal streams at the set switching of electrodes which operate in the optimum mode of heat and mass exchange.

The data obtained by calculations have allowed the design of the gas generation installation with the operational characteristics meeting the requirements set to the devices of such type. At continuous operating mode and nominal parameters of the gas reactor the system is stable and allows gas generation without transition into the thermal kinetic instability mode. Universality of the developed model with the use of dimensionless parameters provides a basis for its application to other similar systems at designing.

Thus, definition of local energy sources in the gas generation systems has allowed carrying out the optimum choice of electrode system in the hydrogen and oxygen reactors of used in various technological processes.