Mass transport in PEM FC gas-diffusion layers and flooding effect

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The diffusion mass transport of reactants in porous systems of gas-diffusion layer of air electrode of the fuel cell was consider. In the conditions when pressure of water vapors is lower than the pressure of saturation the liquid in the layer is absent. Therefore, except for diffusion exchange in porous systems of gas-diffusion layer the convective flow also exists which rate is proportional to the quantity of molecules produced in the layer. We shall designate the rate of this flow as *V.* For gas-diffusion layer it is constant as the molecules are not lost inside it.

For the description of diffusion mass transport in gas-diffusion layer instead of equations of Stefan-Maxwell we shall take advantage of the Fick's law (factors of diffusion of components are close; the concentration of water in a gas phase is low):

{1}

Where: C_i — concentration of components, D — diffusion coefficients in the gas phase.

The equation will allow to solve the system in an analytical way. Solving these equations it is possible to determine the water content in air supplied to the electrode at which flooding of the layer will begin:

{2}

Where D - the thickness of the waterproof layer, C^{sat} — concentration of saturated vapor at the operation temperature of the fuel cell (near 80°C).

Results of calculations under {2} are shown in Fig. 1.

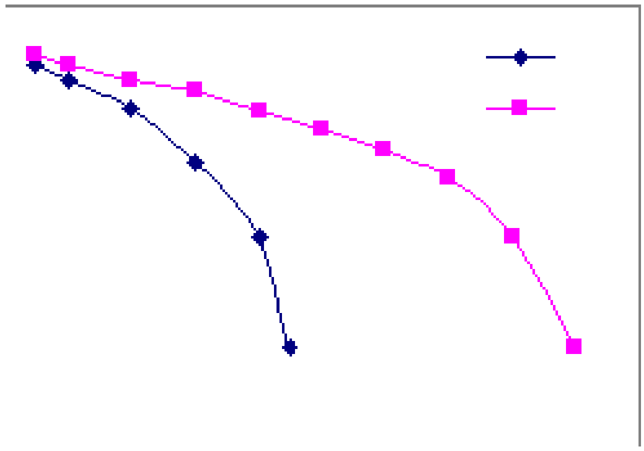

Fig. 1. Border of beginning of flooding of the layer.
For two various portions of surface through which
diffusion outlet of water is occurred.
(as = 10% и 20%), T=80°C, P= 0.3 MPa, nH_2O=0,8

At a low total current when the layer is not flooded, restrictions on transport of oxygen do not limit appreciably the electrochemical process. The increase of current results not in the limitations of diffusion mass transport of oxygen but to the beginning of flooding of the layer. Then the effective section of the layer on gas pores is sharply reduced, and there appear limitations on diffusive transport of oxygen. The data received at the calculations coincide with experimental data.

When diffusion mass transport of water appears to be complicated (low porosity), concentration of water vapor reaches the saturation. Water is condensed in the layer and taken out filtering through porous systems of gas-diffusion and catalyst layers in a liquid state.

Let's consider the behavior of liquid in waterproof porous system of gas-diffusion layer. Water passes through the layer due to a difference of pressure on its sides. We shall assume that the water produced in the catalyst layer filters through the waterproof layer through some chain of pores existing in the layer with the least diameter dcr for given chain. Thus, inside all the layer water will have the pressure determined by this minimal size and superficial tensionson the walls of pores:

{3}

Pores of greater sizes than dcr will be filled with water too. Pores of smaller diameters will be filled with gas. The critical size dcr of pores filled with liquid is possible to find from the following the equation:

{4}

Where: *f(r)* — function of volume distribution of pores on their sizes; 0,31 — the percolation limit. From this equation it is possible to find the diameter above which pores are filled with water and bellow which with gas. Using experimentally received distribution of pores on radius (see Fig. 2), according to the equation it is possible to determine the boundary of water flooding of pores.

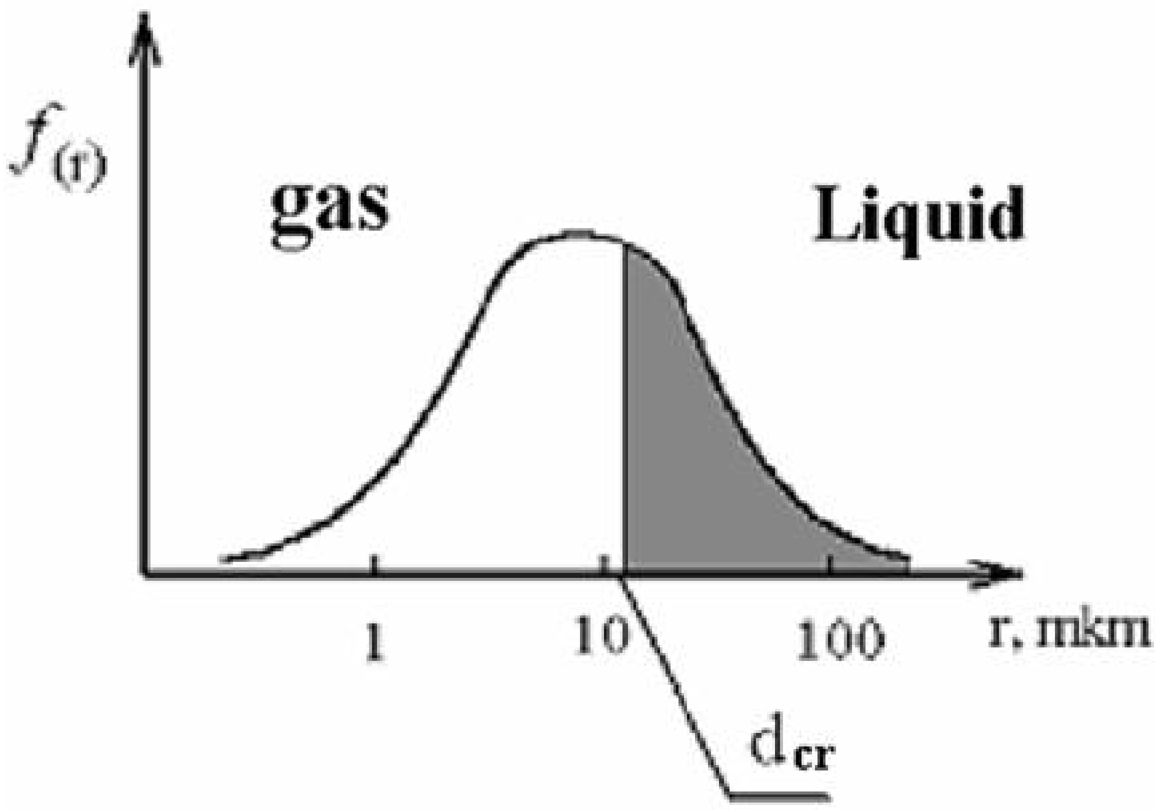

Fig. 2. Distribution of gas and liquid pores on radius