Letter to the Editor

Comment on "Effect of gas diffusion layer properties on the time of breakthrough" by Shahraeeni and Hoorfar

In their recent paper entitled "Effect of gas diffusion layer properties on the time of breakthrough", Shahraeeni and Hoorfar [1] present fluorescence microscopy images of water invading into dry gas diffusion layer (GDL) materials widely used in fuel cell electrodes. Based on analysis of these images, the authors conclude that the GDL water content cannot be found as the product of injection rate and injection time, but this conclusion is completely unjustified.

Application of the law of mass conservation to a control volume containing only the GDL sample and consideration of the fact that water is incompressible results in:

$$\frac{dV_W}{dt} = Q \qquad (1)$$

where V_W is the volume of water in the control volume, t is time and Q is the volumetric injection rate. This equation is valid from the beginning of water injection and until water starts to exit the control volume (i.e. until breakthrough). Integrating between $t = 0$ and $t = t_B$ where t_B is the breakthrough time, with initial condition $V_W = 0$ and a constant injection rate Q one obtains the following expression for the water volume inside the GDL:

$$V_W = Q \cdot t_B \qquad (2)$$

The GDL saturation can be obtained from knowledge of V_W as follows:

$$S_W = \frac{V_W}{V_P} = \frac{V_W}{V_B \varepsilon} \qquad (3)$$

where V_P is the pore volume, V_B is the bulk volume of the sample and ε is the porosity.

By concluding that Eq. (2) does not hold, Shahraeeni and Hoorfar [1] are implying that the law of mass conservation does not hold in their system. The authors' basis for making this assertion stems from their observation that breakthrough times, and therefore GDL saturation according to Eq. (3), in hydrophobic samples were higher than in untreated samples. This is in conflict with expectation, as well as recent experimental findings [2]. Instead of attributing their observation to (a) flaws in their experiment, or (b) non-typical behavior of their materials, they attempted to rationalize their findings with respect to expected trends by developing an alternative method for estimating the overall GDL water saturation. They presented an image analysis technique which showed the hydrophobic GDLs to be less saturated at breakthrough; however, their data are clearly flawed since they are physically impossible. Consider the calculated GDL water saturation vs. time profiles given in their Fig. 3 which show saturation increasing non-linearly. This behavior is not realistic under conditions of constant injection rate since it violates the continuity equation for an incompressible fluid. In reality, the volume of water in the GDL must increase linearly with time according to Eq. (2).

It is impossible from their brief experimental description to determine whether the observed non-linear saturation increase was a real effect due to experimental problems, such as compression of air bubbles, expansion of flexible tubing and water loss through leaks, or due to inadequacies in their proposed image analysis approach. Concerning the latter, it is difficult to accept that the integrated image intensity can be used to determine water content since the GDL matrix material is opaque. This technique has no way of detecting the location and height of water that is visually obstructed by solid, so all this water cannot be accounted for. Furthermore, the presence of visible water does not imply a continuous vertical water column connected to the inlet (as their calculation assumes) since water is free to move laterally in the GDL. One can certainly think of many other plausible reasons for this erroneous result, but it is absolutely certain that mass must be conserved and to imply otherwise, as the authors have done, is fundamentally wrong.

References

[1] M. Shahraeeni, M. Hoorfar, J Power Sources 196 (2011) 5918–5921.
[2] J.T. Gostick, M.A. Ioannidis, M.D. Pritzker, M.W. Fowler, J. Electrochem. Soc. 57 (2010) B563–B571.

Jeff T. Gostick*
Department of Chemical Engineering, McGill University, Wong Building, Room 3060, 3610 University St, Montreal, QC, H3A 2B2, Canada

Marios A. Ioannidis
Department of Chemical Engineering, University of Waterloo, Waterloo, ON, N2L 3G1, Canada

* Corresponding author. Tel.: +1 514 398 4301; fax: +1 514 398 6678.
E-mail address: jeff.gostick@mcgill.ca (J.T. Gostick)

9 May 2011
Available online 2 July 2011