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Numerical Analysis of PEMFC Unsteady Performance Considering Water and Thermal Transport

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1. Introduction

Optimization of the water condition in the PEMFC is a critical factor to increase power generation efficiency, however, water transport behavior in the cell is complicated and difficult to be studied by experimental methods because of the thinness of components of the PEMFC. Combined use of experiments and numerical analysis is better way to understand phenomena in the cell, and the latter is mainly used in this report.

Three-dimensional analytical model considering distributions of temperature and liquid water in GDL and gas channel is developed to estimate unsteady performance of the PEMFC. For estimating gas diffusivity in GDL with liquid water, not only the percentage of water saturation, the effects of droplet size is newly considered in the present model. Effective thermal conductivity and evaporation kinetic coefficient are also considered to have dependence on the abundance of droplet size. Finally, the proposed model was validated by comparing steady and unsteady calculation results with the experimental ones.

2. Analytical methods

Present model considered gas and liquid water transport, electrical equivalent circuit and heat transport described in our previous paper(1). The liquid water transport in channels and GDLs is also calculated. In the channels, the liquid water is supposed to form a film like shape, and the velocity of liquid water was determined by difference of pressure between gas and liquid phase and shear force by the gas flow(2).

In GDL, we have visualized liquid water distribution state by synchrotron X-ray CT, and an example is shown in Fig. 1. The visualized image insisted that the water droplet size distribution varied according to the impregnation modes. The impregnation modes, we assume, consists of transportation by capillary force, condensation, and drying. The droplet size distributions of drying and condensation are plotted in Fig. 2 and the bigger droplet in the condensation mode are clearly observed. In addition, the thermal conductivity and the gas diffusivity through the GDL, we measured, also varied depending on the water impregnation methods. The numerical model could not ignore the dependence of the effects of droplet size or impregnation modes. Then, we have regarded the water droplet as forming two different diameters for representative of various sizes. The multiple droplet diameter model is also applied to evaporation rate.

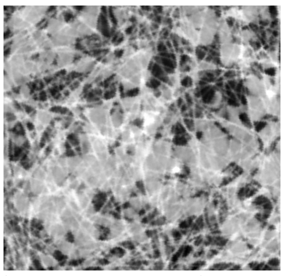

Fig. 1 A synchrotron X-ray CT image of liquid water in GDL

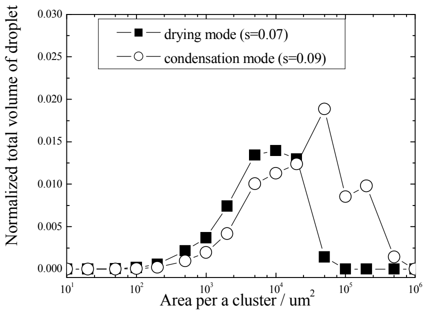

Fig. 2 Measured water droplet size distributions inside GDL

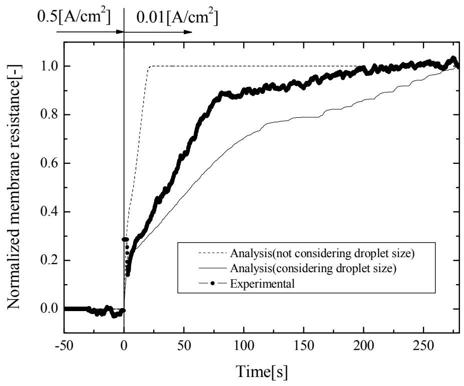

Fig. 3 Measured and calculated responses of membrane resistances after load decrease

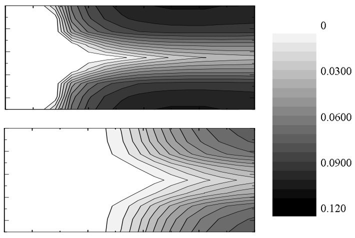

Fig. 4 Calculated water saturation distribution in the GDL. Upper shows 5s, and lower shows 50s after load change

3. Results and discussions

The measured time response of normalized membrane resistances after current density change from 0.5[A/cm^2] to 0.01[A/cm^2] was plotted in Fig. 3 by dots. Because of the decreased amount of generated water by decreased load, the resistivity was increased. The response was not simple and it had at least three flection points. The calculated results with and without consideration of the droplet size effects were also shown in Fig. 3. A calculated response without consideration, dotted line, is a simpler curve with only two flection points and did not accord with the measured response. On the other hands, the solid line considering droplet size was close to the measured plots with also at least three similar flection points. This complicated curve could not calculated by the simple model without consideration of multiple droplet size. The calculated liquid water saturation distribution is shown in Fig. 4, and the difference of water saturation under rib and channel could be a reason for the complicated response.

4. Reference

(1) Araki, T. et al., *Proceedings of MECJ-09*, Vol. 3(2009), pp.157-158.
(2) Qin, C., Hssanizadeh, S., Rensink, D., *Int CHEMICAL ENGNEERING SCIENCE,* Vol.82(2012), pp.223-231.