

Using CFD to Explain Transient Response of a PEM Fuel Cell

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Introduction

Proton Exchange Membrane (PEM) fuel cells produce power for electric drive motors with less pollution. A full-scale three-dimensional solution to the time dependent Navier-Stokes equations for the flow channel and diffusion layers has been developed to investigate the transient behavior of the fuel cell and its performance, which can be changed to meet the requirements of the amplitude and frequency of the load changes.

Some of our steady state works of PEM fuel cell simulation in water management study¹, mass-exchange study between anode and cathode², and temperature effect³ have been achieved. Further Um et al.⁴ showed the transient current overshoot in their model.

In this study, the three-dimensional model of Shimpalee et al.¹ is extended by including time dependent analysis. This is the first three-dimensional full-scale PEM fuel cell with 10-cm² reactive area that includes time dependent examination (shown in Figure 1). Different rates of voltage change are chosen to study their effects on the PEM fuel cell performance at each time interval. Moreover, the detail of local current density, water activity, and reacting gas concentration are investigated.

Numerical Procedure

A control volume technique based on a commercial flow solver, FLUENT, was used to solve the coupled governing equations with time dependence. However, the software requires specification of species source terms and new subroutines were written to calculate the electrochemical and permeability for this simulation. Also FLUENT requires a user-subroutine to account for the flux of protons and water across the membrane.

Results and Discussion

Fig. 2 shows three different rates of cell voltage changes from 0.7 V to 0.5 V, which are step changes (condition #1) and two types of increment change (conditions #2 and #3). The operating flow rates of this study correspond to 1.2 anode stoic and 2.0 cathode stoic at 0.5V. Figure 3 shows the transient average current density corresponding to the rate of cell voltage change as shown in Figure 2. This figure illustrates that when the cell voltage is dropped, there is a current overshoot at that dropping cell voltage due to the potential reduction associated with water activity. Then the current begins to decrease by depletion of reacting gases until it reaches steady state. Moreover, the peak of current overshoot depends on the rate of cell voltage change. Lower rates of voltage change reduce the peak of current overshoot but create more non-uniformity in current density contour.

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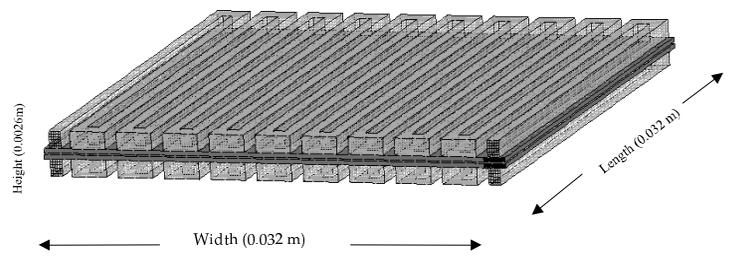


Figure 1. The geometrical model of the complete fuel cell without graphite current collector. There are 20 straight channels connected in a serpentine fashion. Anode-side (top channel) and cathode-side (bottom channel) flow channels are symmetric and placed properly aligned on top of each other¹.

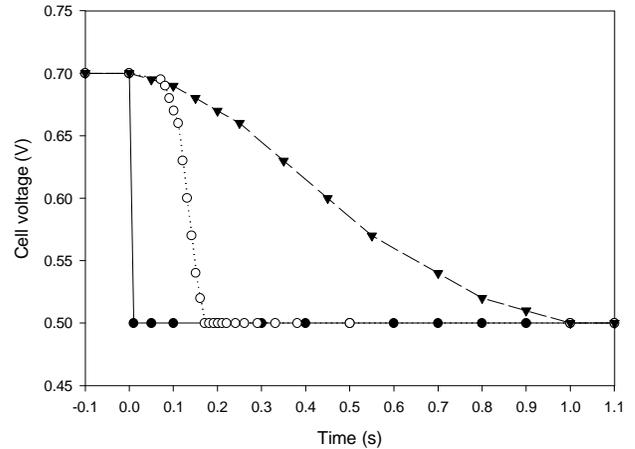


Figure 2. The difference of cell voltage changes with time used in this study. (●) = condition #1: step change, (○) = condition #2: increment change 1, and (▼) = condition #3: increment change2.

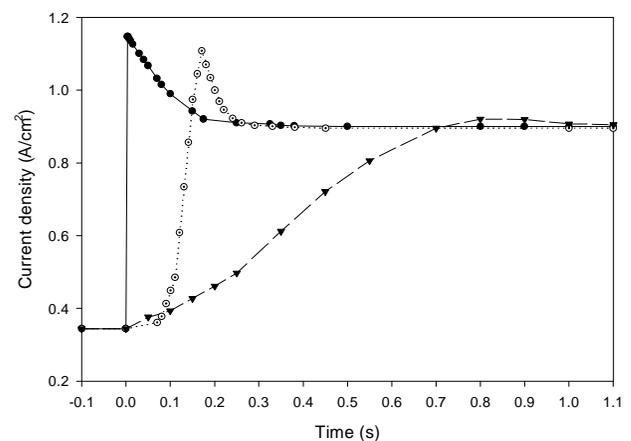


Figure 3. Transient response for average current density with different rates of cell voltage change as shown in Figure 2. (●) = current density for condition #1, (○) = current density for condition #2, and (▼) = current density for condition #3.

References

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