164b Dynamic Modeling and Analysis of PEM Fuel Cells for Startup from Subfreezing Temperatures

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The automotive industry is rapidly moving towards development and commercialization of PEM fuel cells. Fuel cells promise to be an attractive alternative for the internal combustion engine for they are cleaner and more fuel-efficient. More importantly, they enable the goals of reduced-dependence-on-oil and transition to a hydrogen economy. However, still some of the key technology gaps remain that need to be addressed before it is successful. One of the key challenges to the development of commercially viable automotive PEM fuel cells (Polymer Electrolyte Membrane) is the start-up of the fuel cell from frozen conditions. DOE has target of a 30 second start-up from –20 C ambient temperature by 2010. Parasitic power, space and cost constraints make bootstrap start an attractive option, wherein the fuel cell is started up on its own without external heating. Several factors – total ice hold-up, water movement, history of freeze -- determine the success of a bootstrap start from subfreezing temperatures and the subsequent performance decay. Mathematical modeling can be used to understand the phenomenon occurring during a bootstrap start and help us develop better fuel cell stacks for the automotive industry.

In this work, we present a one-dimensional mathematical model that captures the coupling between transport phenomena, phase change and fuel cell electrochemistry. The transport phenomena include mass, momentum and energy transport through various porous layers of the PEM fuel cell. Phase change of water into ice under sub freezing conditions, and evaporation of water, are accounted for in each of the porous layers. The electrochemistry is modeled using a Tafel-type equation for oxygen reduction reaction. A performance curve of the fuel cell during normal operating conditions was simulated with this model and was validated against experimental data. Using this validated model we simulate several bootstrap starts and study the sensitivity of different parameters on the fuel cell performance during the start-up. The parameters that are varied are the total water content in the fuel cell prior to freeze, differential drainage of water on anode and cathode sides prior to freeze, and temperature to which the cell is frozen. Results from these simulations will be presented and discussed.