Numerical Investigation of the High Temperature PEM Electrolyzer: Effect of Flow Channel Configurations

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Abstract

High temperature polymer electrolyte membrane (HT-PEM) electrolyzer (operate above 100 C) is one of the promising candidates for efficient hydrogen production due to higher electrode kinetics, and thus reduces the overpotentials (known as kinetic limitation); lower total thermodynamic energy requirement as compared to liquid water; and lower reversible voltage (calculated from Gibbs free energy change, ΔG). To ensure high performance of hydrogen production, the design of HT-PEM electrolyzer requires careful consideration, especially on the heat and mass transport as well as the electrochemistry.

In this work, we aim to develop a mathematical and numerical framework for the HT-PEM electrolyzer that serves two main objectives: the first involves the study of the fundamental aspect of the HT-PEM electrolyzer and the associated transport and electrochemical processes. The second objective concerns with the development and integration of various flow channel design for high performance hydrogen production. Three different flow channel configurations, namely parallel, serpentine and multiple-serpentine were simulated and compared in term of hydrogen generation, parasitic load arising from pumping power and local temperature profiles.

A single-domain model of a HT-PEM electrolyzer is implemented in the commercial CFD code Ansys Fluent. The non-isothermal model considers conservation of mass, momentum, species, energy and charge (electronic and ionic). Good agreement between model prediction and experimental polarization curves is obtained within the experimental range. The established model is then extended to account for the effect of flow channel designs. The results suggest that multiple-serpentine channel design performs better in term of hydrogen production and uniformity of temperature with reasonable pressure drop.

Keywords: HT-PEM electrolyzer, channel design, model development, validation.