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Modelling optimizes PEM fuel cells to extract peak energy from our fuels – a CFD study

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Abstract Fuel cells are electrochemical energy converters that convert chemical energy of fuel, (typically hydrogen that generation from gasoline, methanol, ethanol, and natural gas by onboard reformer), directly into electrical energy. An optimization study using a comprehensive three–dimensional, multi–phase, non-isothermal, CFD model of a PEM fuel cell that incorporates the significant physical processes and the key parameters affecting fuel cell performance is presented and discussed in detail. The model takes into account convection and diffusion of different species in the channels as well as in the porous gas diffusion layer, heat transfer in the solids as well as in the gases, and electrochemical reactions. This model is used to study the effects of several operating, design, and material parameters on fuel cell performance. Detailed analyses of the fuel cell performance under various operating conditions have been conducted and examined. Optimum operating point for the cell to extract peak energy is also studied in this work. The results indicate that the fuel cell performance under various operating conditions can be optimized depending on the application area. The efficiency of the fuel cell is indeed driven by its economics. Fuel cell designers must select the desired operating range according to whether efficiency or power is paramount for the given application. For most applications, and particularly for steady operation, a fuel cell does not have to be operated at its maximum power, where the efficiency is lowest and both of stresses in the membrane and temperature rise inside the cell are highest. This leads to induce localized bending stresses, which can contribute to delaminating between the membrane and the gas diffusion layers, and lead to a failure of the membrane. When a higher nominal cell potential is selected, the cost of additional cells is offset by savings on fuel cost.

Keywords: PEM fuel cell, CFD modelling, optimization, parametric study, energy.

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