Proceedings of the Canadian Society for Mechanical Engineering International Congress
32nd Annual Conference of the Computational Fluid Dynamics Society of Canada
Canadian Society of Rheology Symposium
CSME-CFDSC-CSR 2025
May 25–28, 2025, Montréal, Québec, Canada

Computationally Efficient Optimization of PEM Fuel Cell Design and Operating Parameters

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Abstract

As the effects of climate change intensify due to overreliance on fossil fuels – accounting for 36.8 Gt of annual greenhouse gas (GHG) emissions, which should be reduced to zero for net zero emissions target set for around 2050 – the need for research into clean energy technologies has become increasingly necessary. Proton exchange membrane (PEM) hydrogen fuel cells have the potential to be used as an alternative for backup, baseload, and mobile power applications. The operation of fuel cells depends on their design and operating conditions, the primarily important parameters include membrane thickness and porosity of gas diffusion layers (GDL) as well as the relative humidity of the reactant gases. Using a steady-state cell-area-averaged technique, a computationally efficient numerical model has been developed in this study to investigate the effects of varying key design and operating parameters on the performance of a PEM fuel cell, while operating under standard conditions of 80°C and 1 atm. Relative humidity levels ranging from 10% to 100% are tested, along with membrane thicknesses of 15 – 250 µm, and GDL porosity from 0.2 – 0.74. Numerical solutions will be utilized to analyze performance metrics, such as power density, cell voltage, and current density to identify activation, ohmic, and concentration losses. These simulations provide a computationally efficient method to optimize parameter values, minimize losses, and enhance real-time fuel cell performance. Observing preliminary results, humidity greatly impacts the membrane hydration accounting for over 90% of the ohmic losses experienced. Reducing membrane thickness has the potential to decrease these ohmic losses. Furthermore, increasing the GDL porosity reduces the concentration losses, as more reactant gases can pass through to the reaction sites to complete the reaction. There is a correlation between these three properties and the three major losses experienced within PEM fuel cells. This work aims to advance the understanding of the design and operating parameters on fuel cell performance, starting with three key parameters of reactant gas relative humidity, membrane thickness, and GDL porosity.