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

Impact of Hybrid Flow Channels on Transport of Reactants and Water in Proton Exchange Membrane Fuel Cells

Ikechukwu S. Anyanwu[1], Amirhossein Amirsoleymani[2], Samaneh Shahgaldi[1*], Xianguo Li[2*]
[1] Hydrogen Research Institute, Université du Québec à Trois-Rivières, Trois-Rivières, QC, Canada
[2] Mechanical and Mechatronics Engineering, University of Waterloo, Waterloo, ON, Canada
*Samaneh.Shahgaldi@uqtr.ca, xianguo.li@uwaterloo.ca

Abstract

The zero-emission, high conversion efficiency, and high-power density of proton exchange membrane fuel cells (PEMFCs) make them a prominent sustainable energy technology, especially in the hard-to-decarbonize transport sector. Parallel flow channel designs, which are commonly utilized in commercial PEMFCs, require specific design characteristics to perform satisfactorily. To ensure adequate reactant delivery to the membrane electrode assembly (MEA) surface, the flow channels must be designed to facilitate reactant supply to the MEA surface, including the land regions between the neighboring flow channels, hence promoting uniform and optimal utilization of the MEA surface. It is also crucial to design flow channels that can efficiently dislodge entrapped liquid water in the electrode region adjacent to the lands between the channels with the help of the reactant gas stream in the flow channels. This work numerically investigates the impact of slant-trapezoidal flow restriction periodically positioned at different locations across selected channels with two different slant-orientation in a 4-channel hybrid arrangement. The influence on cross-channel flow, pressure distribution/loss, and water transport in both the flow channels and neighboring electrode structures is explored applying the transient two-phase flow with the 3-D volume of fluid approach for tracking the interface. It is shown that the presence of slant flow restrictions in different flow field designs enhanced cross-channel flows and becomes prominent when additional flow restrictions are incorporated into every channel. This increase in cross-channel flow is primarily attributable to the fluctuating pressure drop among the channels, which is a result of the flow restrictions' location and orientation. Consequently, the location of the flow restrictions and its orientations in Case 4 exert the most pronounced influence on enhancing the cross-channel flow tendencies when compared to other cases investigated. In contrast, Case 1 demonstrated the least cross-channel flow because of the progressively decreasing pressure distribution peculiar to parallel flow channels. Furthermore, augmenting the number of flow restrictions in Cases 4 and 5 resulted to an increased pressure drop across the channels, thereby enhancing inter-channel activity. Results also suggest that the flow restriction locations are susceptible to water accumulation, as water can easily enter the channel through these locations. While the probability of improving water transport in channels can be enhanced through flow restrictions, channels with slant flow restrictions can also efficiently promote cross-channel flow. This study provides vital insights into cross-channel flows and water transport for hybrid flow channel designs, contributing to the advancement of effective flow channel designs.