Current Distribution on PEM Fuel Cells with Different Flow Channel Patterns

A. Paulino[1], E. Cunha[1], E. Robalinho[2], R. Passos[3], E. Santiago[1]

[1]Instituto de Pesquisas Energéticas e Nucleares, São Paulo, SP, Brazil
[2]Universidade Nove de Julho, São Paulo, SP, Brazil
[3]Universidade Federal do Amazonas, Manaus, AM, Brazil

Abstract

Fuel cells are among important technologies under development in the field of efficient energy generation. Such electrochemical devices convert chemical energy directly into electricity. Proton exchange membrane fuel cells (PEMFCs) are especially attractive due to low operating temperatures and suitability for use in several applications, such as stationary or mobile power generation. The main components of a PEMFC are the membrane-electrode assembly (MEA) and conductive plates with engraved flow channels. The reactant gases are distributed by these channels, generally arranged in parallel, serpentine, or interdigitated patterns. It is important that current be uniform throughout the plane parallel to the MEA, since current distribution and the resulting Joule effect can influence the fuel cell heat and water managements. In the present work, COMSOL Multiphysics® was used to estimate current distribution in different channel patterns of a PEM fuel cell. The serpentine and interdigitated plate patterns shown in Figure 1 were evaluated. A 3D model of an entire 5 cm² cell with 16 channels was chosen for this study. The physics used were Fluid Flow, Mass Transport, and Electrochemistry, for the corresponding parts of the fuel cell. Humidified hydrogen and oxygen were fed into the cell, and the system was considered to be isothermal. The mesh built for this model was structured, with all elements consisting of orthogonal hexahedrons (Figure 2). The polarization curves (Figure 3) show that both patterns have very similar performances. However, when analyzing current densities, it was verified that the current in the interdigitated pattern is better distributed compared to the serpentine (Figure 4). Current density close to the gas entrance is higher than in the exit region, mainly for the serpentine pattern. This happens because current generation depends on gas concentration, according to the equations used in the electrodes. Thus, as the reactants flow along the channels, their concentration decreases, and this behavior is followed by the reaction rate and resulting current. In the interdigitated pattern, the high-concentration gases are distributed more homogeneously, thus current generation takes place in a well-defined but spread area. A uniform heat generation can result in a better thermal management. In addition, regions with different temperatures may cause the cell to operate differently than specified, resulting in water management problems. Therefore, the optimization of the flow channel pattern can lead to better fuel cell performances, and can lead to the choice of better fuel cell designs, particularly in scaled-up cases.

Reference

1. Guilin Hu et al., Three-dimensional numerical analysis of proton exchange membrane fuel cells (PEMFCs) with conventional and interdigitated flow fields, J. Power Sources, v. 136, p. 1-9, (2004)
2. Colleen Spiegel, PEM Fuel Cell Modeling and Simulation Using MATLAB, Academic Press, (2008)
3. Eric Robalinho, Desenvolvimento de um modelo numérico computacional aplicado a uma célula a combustível unitária de 144 cm² do tipo PEM, PhD Thesis, University of São Paulo, (2009)
4. Mass Transport Analysis of a High Temperature PEM Fuel Cell, Solved with COMSOL Multiphysics 4.3a, Model Library.

Figures used in the abstract

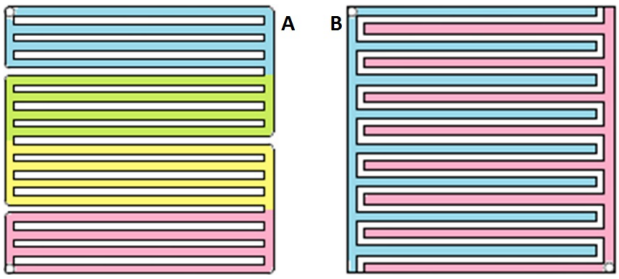

Figure 1: Serpentine (A) and interdigitated (B) patterns.

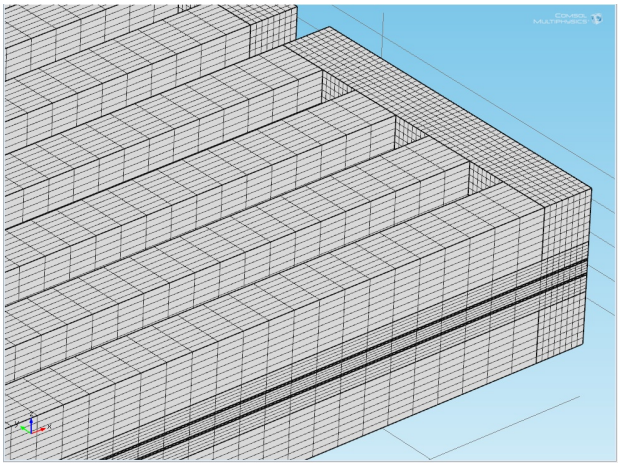

Figure 2: Meshed geometry for the serpentine pattern.

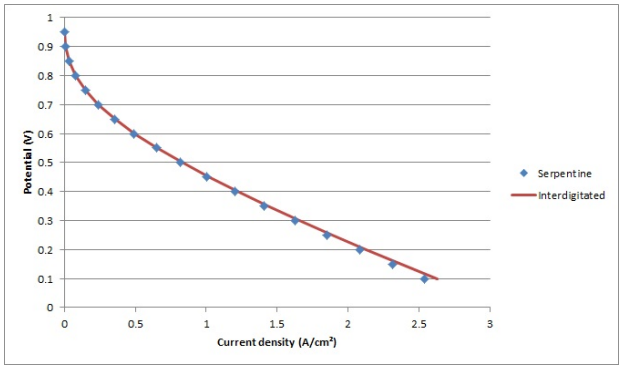

Figure 3: Polarization curves for serpentine and interdigitated patterns.

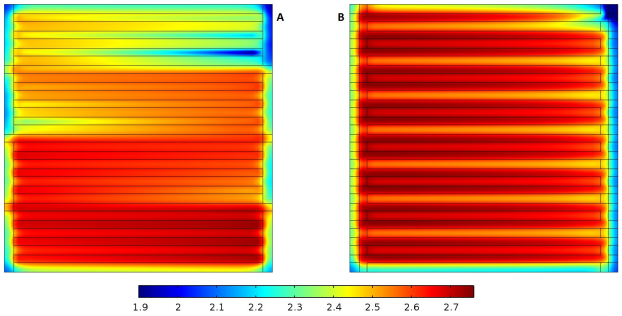

Figure 4: Current density (A/cm²) in serpentine (A) and interdigitated (B) patterns.