Numerical Modeling of a Microtubular Solid Oxide Fuel Cell Using COMSOL Multiphysics®

P. Pianko-Oprych[1], E. Kasilova[1], Z. Jaworski[1]

[1][1]West Pomeranian University of Technology, Faculty of Chemical Technology and Engineering, Szczecin, Poland

Abstract

Micro-tubular Solid Oxide Fuel Cells are attracting more and more interest as new generation of environmental friendly energy conversion devices useful in the power generation solutions. The main advantages of this promising fuel cell technology are the following: mSOFCs are flexible in the choice of the fuel, they can work based on hydrogen, propane, mixture of propane and butane (LPG); they are the most efficient fuel cells with electrical efficiencies around 48%; high temperature of the mSOFC produces additional heat, which can be used in co-generation applications and finally they are appropriate for either stationary power generation solutions as well as for mobile power units of small size.

Although commercial applications of mSOFC still suffer from high costs related to interconnectors and seals resistant to high temperature, a clear need of further improvement of the cell performance and durability can be seen along with necessity of shortening the time of the cell start-up. While the first issue has been already solved by development new materials, which enable mSOFCs increase their performance, the latter problems related to mSOFCs lifetime and quick start-up/shut down are still major challenges to be met. To resolve those challenges, knowledge of the distributions of species concentration, temperature and current density in the mSOFCs is essential. However, the operating conditions are difficult to obtain from experiments. Therefore, researchers are searching for additional data and tips how to improve the mSOFCs performance which can be obtained from CFD (Computational Fluid Dynamics) modelling.

Use of COMSOL Multiphysics® with the additional Batteries & Fuel Cells Module to model a micro-tubular Solid Oxide Fuel Cell is briefly described in the paper. Simulations of reformed propane flow coupled with mass, species and charge transfer in a mSOFC were performed and compared with experimental data. In the simulations the charge transfer reaction was treated as a bulk reaction instead of widely-used surface-lumped approach. The concentration dependence of activation polarization was taken into account by a general form of the Butler-Volmer equation, while the concentration polarization was neglected. The inner surface of the anode was grounded, which means that its electric potential was set equal to zero, while at the cathode outer side the electric potential was set equal to 0.8[V]. The current collectors were defined as ideally uniform mesh collectors. The obtained numerical curves of the voltage and power density vs. current density corresponded well to the experimental data.

Therefore, COMSOL Multiphysics® can provide valuable information about temperature and species concentration gradients in the mSOFCs in two/three dimensions, which are not available from measurements. This type of information is also not available from a simple one-dimensional modelling approach.