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Numerical study of performance optimization in a proton exchange membrane fuel cell

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Abstract. Some parameters such as $i_{a,ref}$, $c_{H,ref}$, $i_{c,ref}$, $c_{O,ref}$, α_a and α_c that affect the PEMFC performance are numerically studied in the present work. To reveal the effects of the above parameters on the cell performance, several parameter groups have been presented. The results show that different parameter values may result in a wholly identical polarization curve when the parameters agree with a given function. The function indicates the effects of several parameters and can be used to direct the optimization of PEMFC performance.

Key words

Proton exchange membrane fuel cell; Parameter; Numerical analysis; Polarization curve; Optimization

1. Introduction

The proton exchange membrane fuel cell (PEMFC) is considered to be a promising power source, especially for transportation and stationary cogeneration applications due to its high efficiency, low-temperature operation, high power density, fast startup, and system robustness. Recently, many computational models have been developed and published to reveal the fundamental transport phenomena taking place in the PEMFC and to optimize the PEMFC performance. There are many parameters that affect the PEMFC performance which have been studied by many researchers. Stockie et al. [1] performed a sensitivity study of a PEMFC model. It was found that the PEMFC performance is obviously affected by some parameters. Chan and Tun [2] developed a model of catalyst layer and investigated the effects of the cathode reference exchange current density, reference oxygen concentration, oxygen diffusivity and catalyst layer porosity on PEMFC performance. Lum and McGurik [3] developed a model of the cathode of a PEMFC with an inter-digitated gas distributor with the intention of studying the effects of various parameters such as electrode permeability, thickness and shoulder width. Al-Baghdadi and Al-Janabi [4] developed a three-dimensional model of a PEMFC to investigate the effects of various parameters such as proton exchange membrane thickness, diffusion layer porosity, diffusion layer thermal conductivity on the fuel cell performance. Chu et al. [5] investigated the porosity of gas diffusion layer (GDL) of a PEMFC. The results showed that a non-uniform porosity of GDL is necessary to improve the performance. Du et al. [6] investigated the effects of the effective proton and electronic conductivity of the catalyst layers on PEMFC performance. Crujicic et al. [7] performed a sensitivity analysis to determine the effect of six parameters on a PEMFC performance. The results showed that, while the predicted average current density at the membrane/cathode interface is affected by uncertainties in a number of model parameters, the optimal designs of the PEM cathode and the interdigitated air distributor are quite robust. Wu et al. [8] also found some operating parameters have strong impacts on the PEMFC performance. Min et al. [9] investigated the influence of some parameters on the performance. They classified the parameters according to their influence on the fuel cell as: insensitive, sensitive, and highly sensitive. Furthermore, they found that different parameter values may result in a nearly identical polarization curve of a PEMFC, and hence they concluded that polarization curve only is insufficient to validate the PEMFC model.

The present work focused on the effects of six parameters on the PEMFC performance. Some functions formed by several parameters were presented to indicate the effects.