Homogenization method applied to the mechanical behavior of the active zone of a Proton Exchange Membrane Fuel Cell

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Abstract

Proton Exchange Membrane Fuel Cells (PEMFC) consist of a stack of cells. A sealing zone is located at the periphery of the cell, while the electrochemical reaction occurs at the center of the cell. This latter is referred as the "active zone"; the cell consists of an assembly of two components: the BiPolar Plates (BPPs) are used to facilitate the flow of the reactants to the Membrane Electrode Assembly (MEA). The MEA consists of a porous media, called the Gas Diffusion Layer, a Catalyst Layer and a Proton Exchange Membrane (PEM). The cells are then clamped together using End Plates (EP). This process is essential and must provide sufficient clamping pressure to seal the device with optimal compression of the active zone (1).

The components have disparate thickness scales, ranging from a few micrometers for the catalysts layers to tens of centimeters for the stack. To improve PEMFC performance, it is necessary to understand the associated complex mechanical behavior that occurs from the land/channel pattern through the entire device during the clamping process and operation. Numerical simulation using the finite element method is an effective tool to achieve this objective. In the literature, there are numerous 2D models to understand the impact of the assembly pressure on the MEA (2). However, only a limited number of studies have focused on the spatial stress heterogeneities resulting from clamping (3). The main challenge in simulating the whole stack is to reduce the computational time. In fact, this patterned compression generates a significant number of contact. Moreover the mechanical behavior of the porous media is highly nonlinear, with irreversible strain under cyclic compression (4), and the difference in thickness between all components generates a considerable number of degrees of freedom. Therefore, a homogenization method was chosen in this study to limit the computation time while maintaining high accuracy of macroscale calculations. It also provides information on the stress and strain levels on a smaller scale (5).

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This study proposes an original approach to homogenize the mechanical behavior of the active zone, by integrating the non-linear and irreversible behavior of the GDL. The homogenized model is then compared with experimental data. Finally, it is implemented in a stack model to demonstrate the importance of clamping process control on system performance by identifying the zones where the heterogeneities occur during operation.

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