Design of Experiments to Evaluate Material Characteristics of Porous Transport Layers in Polymer Electrolyte Membrane Fuel Cells

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We report on design of experiments (DoE) techniques applied to the modeling and characterization of in polymer electrolyte membrane fuel cell (PEMFC) performance. The focus on conventional operating conditions (temperature, pressure, relative humidity, etc.) has been extended to incorporate the effects of material properties (e. g, hydrophobicity), and membrane electrode assembly (MEA) architectures.

The MEA is the basic repeating unit in PEMFC stacks. The state-of-the-art design consists of a catalyst layer (CAL), a micro-porous layer (MPL), and a gas diffusion layer (GDL) on either side of a proton exchange membrane (PEM). There are significant knowledge gaps that prevent linking the structures to the functions within the MEA materials. Notably, there are no reliable predictive models to guide design optimization, and the experimental and materials developments continue to rely on trial and error.

Single parameter testing is time-consuming and expensive. Even with accelerated methods, it is difficult to account for multiple-parameter interactions. DoE techniques use statistical methods to minimize the number of required measurements, and to quantify concurrent interactions explicitly. Full and fractional factorial designs or Taguchi methods enable efficient testing and they can determine the statistical significance of factors and factor interactions. We report the analysis of different GDL and MPL parameters employing two factorial designs.

First, we applied a general factorial design, with seven factors and three responses. The factors included the numeric factors for anode and cathode stoichiometry, cell and gas inlet temperature, anode and cathode gas inlet relative humidity as well as two additional categorical factors (pressure and MEA architecture).

For the second (full factorial) design, the factors were based on GDL material parameters only. The response was the cell's voltage at different sets of operating conditions. Table 1 describes the selected factor values. The statistical models were developed with the aid of Design-Expert 8, and the measurements were carried out on a PEMFC hardware described elsewhere[1].

The resulting empirical relations combined with an analysis of the measured thermodynamic gradients can be used to, for example, quantify the influence of the PTFE content on cell performance over a broad range of operating conditions. Beyond such specific characterization, the present work provides a generalized method to quantify the relative importance of material properties versus operating conditions on overall cell performance.

Table 1: Selection of factor values

Factor Coded Name	**Factor Name**	**Range of values**	**Factor type**
A	PTFE content	5 – 20 wt.%	Numeric
B	Type of PTL	With MPL or without MPL	Categorical

References:

1. M. Blanco, D. P. Wilkinson, and H. Wang, *International Journal of Hydrogen Energy*, **36**, 3635–3648 (2011) http://www.sciencedirect.com/science/article/pii/S036031991002450X.