Long-Term Performance Characterization of Proton Exchange Membrane Fuel Cells

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Introduction

As Proton Exchange Membrane Fuel Cell (PEMFC) technology continues to mature, fundamental understanding of component durability must become the focus of development over the remainder of this decade. Fulfillment of promises of the technology's ability to solve energy security problems depends on improvements in reliability and durability of PEMFC stacks, as well as realizing the necessary cost reduction that remains. Methods to predict and quantify how state-of-the-art and next-generation components will affect stack lifetimes will improve the overall reliability of commercial systems. It will not always be convenient, or even completely informative, to simply build a durability stack/cell with the component of interest and acquire 5000 hours of data. Component interactions and effects of operating conditions must first be understood in order to explain why a particular performance pattern or decay rate is seen.

Set point or load cycling [1,2], as well as accelerated life testing, can provide insight into degradation mechanisms that can then be used together with steady-state, performance-decay data. The objective of this work is to look at less conventional methods of analyzing durability data such as time-dependent measurements of cyclic voltammetry (CV), electrochemically active surface area, polarization data, cell impedance, and product-water composition. In addition, drive cycling of set points has been performed to examine the affect of frequent changing of operating conditions.

Experimental

Figure 1 shows successive CV plots as a function of time, taken every ~100 operating hours. The MEA used was an in-house, hand-made one consisting of a Pt anode (20% Pt/C, E-TEK, Natick, MA) and a Pt_3Cr cathode (20% Pt_3Cr/C, E-TEK, Natick, MA) with areal loadings of 0.20 ± 0.01 mg Pt/cm^2 for both electrodes. The Nafion® content in both catalyst layers was 28 wt%, the membrane type was Nafion® 112, and the active area was 5 cm^2. ELAT^{TM} Version-2, cloth-based gas diffusion layers with a double-sided microporous layer were used. The cell was operated under constant current at 1.07 A/cm^2. Cathode-side H_2 adsorption-desorption CVs are seen gradually moving up the y-axis (Fig. 1) with increasing test time, especially beyond 500 hours. This shift was due to reactant gas crossover, which may have arisen from membrane pinhole formation or chemical degradation.

A corresponding plot of the time-dependent mass-transport behavior is shown in Figure 2. The y-axis represents current density values within the low-V region of successive polarization curves. A performance decrease is observed with increasing test time due to limitations introduced from the long-term operating environment. Drive-cycle data at ~3500 cycles is shown in Figure 3, with a noticeable gap between the set point power (black line) and the response power (gray line). This gap has been found to increase with the number of cycles, indicating increased performance limitations.

References
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[2] R.M. Darling and J.P. Meyers, *J. Electrochem. Soc.*, **150**, A1523 (2003).
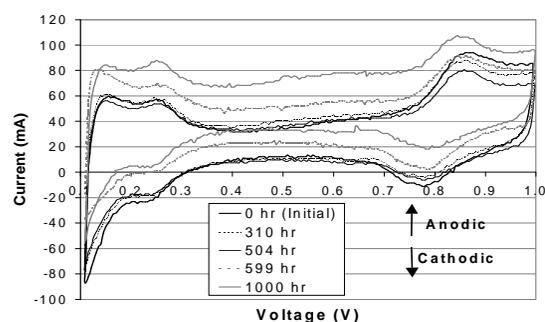
Figure 1. Successive H_2 adsorption-desorption CV plots for the cathode at different lengths of testing time. CV Set Points: Anode H_2 Flow Rate = 133 sccm, Cathode N_2 Flow Rate = 550 sccm, Scan Rate = 100 mV/s, T_{Cell} = 80°C, Anode/Cathode $T_{Humidifier}$ = 105/80°C, Gas Pressures = 30 psig. See Fig. 2 for durability conditions.
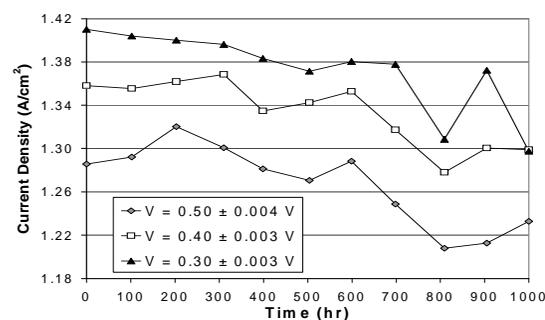
Figure 2. Mass-transfer region performance as a function of durability testing time. MEA active area = 5.0 cm^2; Current = 5.34 A (1.07 A/cm^2); H_2/Air Flow Rate = 133/550 sccm; Gas Pressures = 2.8 atm abs. (30 psig); Anode/Cathode Humidity = 100%/100%; $T_{Humidifier}$ = 80/105°C (Anode/Cathode); T_{Cell} = 80°C.
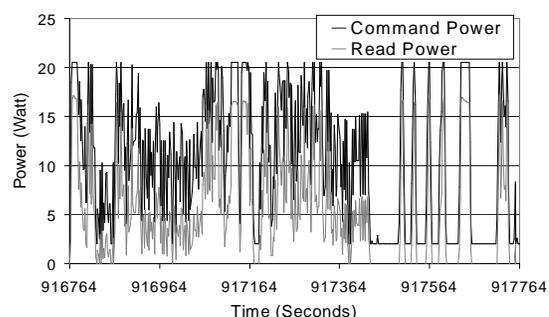
Figure 3. Set point and response power at drive cycle ~3500 (at 255 hours of total cycling time).