

Evaluation of transient water content during PEMFC operational cycles by stroboscopic neutron imaging

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Neutron imaging has been extensively used to study water transport and retention within proton exchange membrane fuel cells (PEMFCs). Studies have been motivated by the observation that well-moderated water transport in a PEMFC system is critical for optimizing performance and minimizing degradation under a variety of operating conditions. Some of the most demanding (most interesting) conditions for PEMFCs occur under dynamic operation; i.e. startup/shutdown or the varying power requirements of an automotive drive cycle. However, due to the limited flux from available neutron sources, the rapid water transients associated with these conditions have only been considered at larger length scales (flowfield and stack studies), while high-resolution studies (component scale) have been restricted to steady-state behavior [1]. X-ray based imaging methods have proven to be useful alternatives for high temporal and spatial resolution [2, 3], but the wide cell material and construction choices compatible with neutron imaging make expanded application desirable. It has been previously shown that careful isolation of cyclic behavior (a stroboscopic method) can circumvent the limitations of neutron flux [4]. The present work demonstrates that this strategy can be effectively applied to PEMFC operational cycles and the capture of rapid water transients.

Cells were assembled using Ion Power catalyst-coated membranes (CCMs) and SGL gas diffusion layers (GDLs). Gold-coated aluminum hardware was used with active area of either 1 cm² or 50 cm², for high and low spatial resolution imaging, respectively. Cells were operated using a modified U.S. DRIVE Fuel Cell Tech Team (FCTT) durability protocol, with combined current and humidity variation. Cells were imaged in continuous neutron exposure, with the detector output divided into 5 second images. These images were carefully averaged at the same point across multiple operational cycles (about 1000 seconds apart, as illustrated in Figure 1), generating a representative series for the durability protocol with ~5 second temporal resolution and down to ~15 μm spatial resolution. Cross-sectional water profiles were calculated for the smaller cells (1 cm²), allowing evaluation of the water content in the individual components, and these profiles were compared to the total water content in different regions of the larger cells (50 cm²).

Water thickness time traces from a cell cross section are shown in Figure 2. The water content at three different layers across the cell thickness – in the CCM, cathode GDL and anode GDL – is averaged from 41 operational cycles. A comparison with the time trace for the cathode GDL with no averaging shows the vastly improved signal/noise achieved. Water transients in the cathode GDL occur over tens of seconds in response to current density and humidity variation, while the CCM shows slower transitions. Similar data from different cells are

used to investigate the effects of internal heat generation, varied upstream conditions, and alternate GDL combinations.

References

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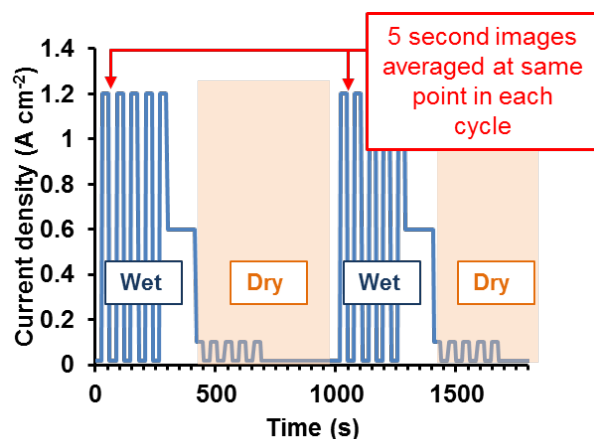


Figure 1: Modified U.S. DRIVE FCTT cell durability protocol, combining current and humidity cycling in a ~1000 second loop. “Wet” periods were simulated by humidifying both gas streams to an 83°C dewpoint. In “Dry” periods the cathode humidifier was bypassed (anode stream remained humidified). Cell water content was quantified by 5 second neutron images, averaged at the same point in each cycle to increase signal/noise.

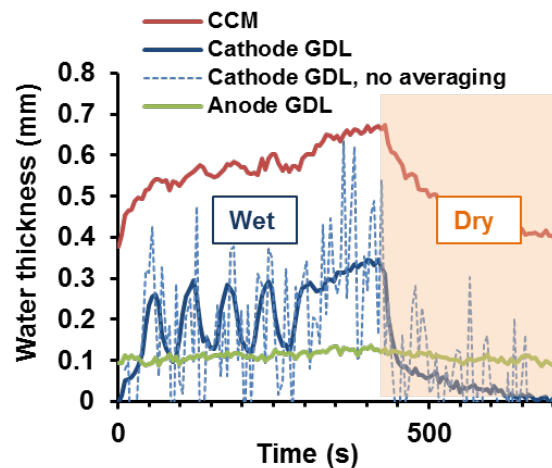


Figure 2: Water thickness time trace calculated for three different components in a cell cross section during the durability protocol. Values for the CCM, cathode GDL, and anode GDL are calculated from the average of 41 cycles. The time trace for the cathode GDL is also shown for a single cycle, to demonstrate the improved signal/noise. Cell: Dupont XL membrane, Pt/C electrodes (0.05/0.25 mg Pt cm⁻² An/Ca), SGL GDLs (24BC/25BC An/Ca), H₂/Air, 80°C.