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Empirical Lifetime Prediction Model for Heavy Duty Bus Fuel Cell Membranes

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Development of durable membrane electrode assemblies (MEAs) is essential for widespread commercialization of fuel cell buses. The bus duty cycle exposes fuel cell membranes to conditions that can eventually lead to membrane degradation, and may ultimately limit the fuel cell lifetime in this application.

Load transients in bus fuel cells may induce rapid swings in membrane degradation stressors, such as voltage, temperature, and membrane humidity. During periods of idling, high cathode potentials result in elevated rates of gas crossover through the membrane. Gas crossover is known to accelerate chemical membrane degradation due to elevated hydrogen peroxide formation[1] resulting in radical attack[2], leading to subsequent membrane failure, mainly in the form of gas leaks through the membrane.

Accelerated membrane durability tests (AMDT) apply enhanced levels of stress, such as elevated voltage and temperature, and severe relative humidity cycling, to ensure rapid membrane failure. Results have shown to be in good agreement with failures observed in historical bus field trials. The objective of the present research is to develop a bus specific lifetime prediction model based on results from AMDTs for membrane lifetime estimation under bus conditions. Novel durable MEA concepts will be tested under AMDT conditions and considered in the lifetime prediction model.

The lifetime prediction model is based on the response surface method. The full factorial design of experiment (DOE) uses two parameters, i.e. voltage and RH cycling regime, which are tested at two levels. The main effects of the parameters as well as their interaction are evaluated with an ANOVA study. Two center points are included in the DOE, in order to better assess non-linear properties.

AMDTs are executed with a 10-cell stack, where all cells are assumed to be exposed to identical conditions. This allows for a statistical analysis based on the individual leak rate of each cell. Some differences in the failure modes during the AMDT at the two different levels of voltage and RH cycling regimes have already been observed. These differences include the number and size of leaks; the leak initiation and growth time, the overall number of failed MEAs in the stack, and the amount of platinum dissolution and precipitation in the membrane.

The empirical model focuses on extrapolating the lifetime of membranes under AMDT conditions to a lifetime expected under actual bus conditions. The two main voltage levels, plus the voltage levels applied in the center points, are used to calibrate for the entire scope of voltages observed during bus operation. Each voltage level will therefore have an expected lifetime, which is then used to calculate a final bus membrane lifetime using a weighted average.

Two severe RH cycling regimes are used in the AMDTs to accelerate degradation of the membranes by adding mechanical stress at levels much higher than would be expected in bus duty cycle operation.

An Arrhenius function is applied to extrapolate from AMDT temperature to expected operational temperatures. Differences in precipitated platinum levels between the AMDT and those expected due to duty cycle operation are accounted for the in the membrane lifetime predictions.[3] The difference in end of life failure criteria for bus operation compared to the criteria for failure in the AMDT is also accounted for in the empirical model.

The obtained empirical lifetime prediction model based on AMDT results is expected to become a useful tool for industry based product evaluation.

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References

[1] M. Inaba, T. Kinumoto, M. Kiriake, R. Umebayashi, A. Tasaka, and Z. Ogumi, *Electrochimica Acta,* vol.51, pp.5746-5753, 2006.

[2] T. Madden, D. Weiss, N. Cipollini, D. Condit, M. Gummalla, S. Burlatsky, and V. Atrazhev, *J. Electrochem. Soc.*, vol.156, no.5, pp.B657-B662, 2009.

[3] N. Macauley, L. Ghassemzadeh, C. Lim, M. Watson, J. Kolodziej, M. Lauritzen, S. Holdcroft, and E. Kjeang, *ECS Electrochemistry Letters*, vol.2, no.4, pp.F33-F35, 2013.