

Failure Prediction of Membrane Electrode Assemblies for Proton Exchange Membrane Fuel Cells

January 2016

A thesis submitted in partial fulfilment of the requirements for the degree of
Doctor of Philosophy in Engineering



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Thesis Abstract

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Thesis Title Failure prediction of Membrane Electrode Assemblies for Proton Exchange Membrane Fuel Cells			
Thesis Summary In Proton Exchange Membrane Fuel Cells (PEMFCs), the Membrane Electrode Assembly (MEA) remains the limiting factor for both cost and durability. While the chemical and thermal behavior of the MEA has been well studied, there is still a lack of data on the mechanical behavior and failure mechanism of its components. The objective of this dissertation is to develop the mechanical model to predict the failure of MEA. On top of that, numerical models are developed to complement the experimental results. Chapter 1 summarizes the background and previous studies. Chapter 2 gives a detailed overview of the structure of a PEMFC stack, and of the state of knowledge of the materials that compose it. The constraints faced by each component are discussed, and the importance of focusing on the mechanical failure of the MEA is clarified. In Chapter 3, the crack initiation inside the MEA is investigated. A numerical scheme is proposed in order to corroborate experimental results. A failure criterion for determining the failure from fatigue of the catalyst layer is introduced and shown to accurately predict the onset of failure in the catalyst layer. Finally, using insights from the numerical model, the mechanism of Nafion slippage is introduced as a possible explanation for the origin of cracks in the catalyst layer. In Chapter 4, the constitutive model of proton exchange membrane is discussed based on the phenomenological analysis of molecular chain deformation. A least square optimization is conducted in order to ensure the best possible fit of experimental stress-strain curve throughout the entire range of strains. The resulting constitutive model is shown to be of satisfying accuracy for the purpose of fracture modeling. In Chapter 5, the fracture resistance of proton exchange membrane is investigated. The results of a double-edge notch tensile (DENT) test are shown for different environmental conditions, giving insights on the fracture resistance of the membrane. The essential work of fracture is shown to be heavily dependent on both temperature and humidity, with temperature being the dominant factor, as is further demonstrated by observing the fracture surfaces on a scanning electron microscope. In Chapter 6, a numerical model aimed at reproducing the result of the DENT test is introduced. The model is shown to be able to accurately estimate the essential work of fracture of proton exchange membrane. The analysis of the data allows to confirm the results of the previous chapter, as well as to further clarify the mechanisms of fracture. Chapter 7 summarizes the conclusion of this dissertation.			