Ultrasonic Sealing of PEM Fuel Cell Membrane Electrode Assemblies

by

Todd T. B. Snelson

An Abstract of a Thesis Submitted to the Graduate

Faculty of Rensselaer Polytechnic Institute

in Partial Fulfillment of the

Requirements for the degree of

DOCTOR OF PHILOSOPHY

Major Subject: Mechanical Engineering

The original of the complete thesis is on file
In the Rensselaer Polytechnic Institute Library

Examining Committee:

Professor Stephen Derby, Ph.D., Thesis Adviser

Professor Thierry Blanchet, Ph.D., Member

Professor Charles Malmborg. Ph.D., Member

Professor Daniel Walczyk, Ph.D., Member

Rensselaer Polytechnic Institute
Troy, New York

April, 2011
(For Graduation May, 2011)

ABSTRACT

An alternative to fossil fuels will need to be implemented on a world wide scale in order to maintain our current standard of living without adversely impacting the environment. Solar, wind, and other renewable energies are abundant and clean sources that are currently underutilized primarily due to high cost compared to fossil fuels. Fuel cells can be a part of the solution to our energy and environmental problems. For example, solar energy can be used to generate hydrogen, which can be stored and then used with a fuel cell to convert the hydrogen to electricity and heat for your home or transportation when and where you need it. In order to have fuel cells and their subassemblies, including Membrane Electrode Assemblies (MEA), become commercial viable products, the MEA production cycle times will need to improve from minutes to seconds or milliseconds. The MEAs will also need to be produced more affordably and with higher quality standards to meet the anticipated demand. Sealing the MEAs with ultrasonic bonding provides an alternative assembly process to the current practice of pressing components between heated tools using a hydraulic press. Ultrasonic sealing can improve the manufacturing cycle time by an order of magnitude while consuming a fraction of the energy for less capital expenditures all while improving the performance of the MEA.

The details of the theory behind ultrasonic bonding with the application of a relatively small vibration (around 20 microns) at a high frequency (in the range of 20,000 cycles/second) to achieve the heating and bonding of dissimilar materials are viewed more as "black magic" in that the manufacturing process has been utilized in production for many decades, but the theory behind the processes is not completely understood. This research investigates the optimal parameters to ultrasonically seal a high temperature membrane between two electrodes with validation on fuel cell test stands. A mathematical model is derived from vibrational theory and, based on the optimal physical ultrasonic sealing parameters, is combined with the experimentally measured physical properties of the membrane and electrode materials to predict the energy dissipation for each material layer during the ultrasonic sealing of the MEA. A multi-physics simulation expands upon the energy dissipation from the mathematical model and predicts the temperature distributions within the MEA during the ultrasonic

sealing process. The temperature distributions of the multi-physics model are validated with comparison to the MEA interface temperatures obtained with hair thin thermocouples placed between layers of the MEA during the ultrasonic sealing process.

The resulting optimized ultrasonic sealing processes and predictive engineering simulation models will assist in the facilitation and implementation of an ultrasonic bonding system into an automated MEA production line, thus advancing the fuel cell component manufacturing one step closer to commercial viability.