System Control and Efficiency Measurements for a Portable High Temperature PEM Fuel Cell System with Onboard Fuel Processor

Ramesh Koripella, Allison Fisher, Stephen Rogers and Steve Samms
Motorola
Microelectronics and Physical Sciences Laboratory
2100 E. Elliott Rd, Tempe AZ 85284

On board generation of hydrogen fuel using methanol steam reforming in a miniaturized reactor is one of the options for supplying fuel for portable fuel cells. The output from the methanol steam reformer typically contains 1-2%CO and is unsuitable for low temperature PEM fuel cell use. An additional reactor to preferentially oxidize the CO from the steam reformer output stream is required to bring the CO levels suitable for the low temperature PEM fuel cell use. This process requires more controls and increases the system complexity. Another alternative approach is to use a high temperature PEM fuel cell operating at 180-200°C which can use the output from the methanol steam reformer directly. This approach can potentially simplify the system design. Our methanol fuel processor consists of a fuel vaporizer, a steam reformer and a catalytic combustor. The methanol vaporization and the steam reforming reaction require heat inputs and the catalytic combustor provides the required heat by combusting some of the methanol fuel or the hydrogen gas generated from the steam reforming reaction. The high temperature PEM fuel cell stack requires heat input to heat the fuel cells to operating temperatures of 180-200°C. While the fuel cell stack is in operation, inefficiencies in the fuel cell also generate heat. Careful balance of fuel processor and fuel cell outputs and thermal integration of these two units is required for better system efficiencies.

A small fuel processor measuring 2”x 2” x 0.25”, capable of producing sufficient hydrogen for a 1W size fuel cell was fabricated using the multilayer ceramic technology and insulated with a 0.5” thick microporous insulation on all surfaces. Initially the fuel processor was brought to the required operating temperatures by combusting hydrogen and air in the catalytic combustor. Once the device was hot and producing sufficient hydrogen gas, the output from the reformer was fed into the combustor to self sustain the reforming reaction without the addition of external hydrogen fuel to the catalytic combustor. A computer based control scheme was implemented to control an electronic valve to limit the amount of H_2 fed into the combustor and maintain a constant temperature (±5°C). While the device was in operation, liquid fuel inputs and the gas outputs were carefully measured. Under the steady state operating conditions, the energy inputs required to self sustain the fuel processor at the operating temperatures were measured. A planar fuel cell stack with four cells connected in series was assembled using the PBI-MEA. Performance of the PBI planar stack was evaluated under H_2/air and simulated reformate gas (mixture of 75.8%H_2, 23.2%CO_2 and 0.95%CO) /air conditions. This fuel cell was integrated with the fuel processor by connecting the output from the fuel processor to the fuel cell. Both devices were insulated with a 0.5” thick microporous insulation all around it. Again a computer based control scheme was implemented by controlling an electronic valve to control the amount of H_2 fed into the combustor or the fuel cell to maintain a constant reformer temperature. Energy inputs and outputs for the combined integrated device were estimated from the measured flow rates of methanol liquid input, the output gas measurements, and the fuel cell power output. Using this information, efficiency estimates under optimum operating conditions were made for this particular integrated fuel processor and the fuel cell system design. Issues with the current control scheme and designs for a better control scheme will be discussed.