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Initial experiments with a Pt based heat exchanger methanol reformer for a HTPEM fuel cell system

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Motivation

The use of a liquid reformed hydrocarbon as fuel for fuel cells can reduce fuel storage volume considerably. The PBI membrane technology used in high temperature PEM (HTPEM) fuel cells has great advantages when using reformat fuel gas compared to low temperature PEM fuel cells (LTPEM).

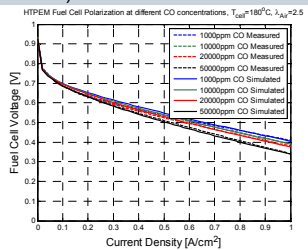


Figure 1: Simulation and measurements of a single HTPEM fuel cell at different CO concentration levels.

A standard industrial catalyst coated plate heat exchanger has been designed for the production of hydrogen rich gas for a HTPEM fuel cell stack. The advantages of the heat exchanger is contained in the design ensuring good heat transfer and compactness.

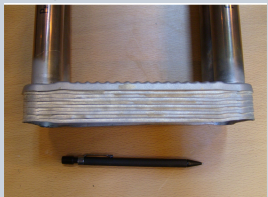


Figure 2: 1 kW Pt catalyst coated heat exchanger methanol reformer.

The operating conditions for the reformer is at temperatures from 300-500 °C. This work presents some of the initial tests and conclusions made on the reformer.

Methanol Reformer Test

The heat exchanger reformer consists of two separate flow branches, operating in co-flow. One side is the reformer side, where a mixture of evaporated water and methanol is presented and steam-reformed to a hydrogen rich gas. The steam reforming process is exothermic and is supplied with heat from the second flow branch, which is a catalytic burner, where hydrogen and air is mixed, and combusted over a catalyst. For the initial test, the evaporation of the fuel water/methanol mixture is done by electrical heaters, but could be integrated with the burner side of the heat exchanger.

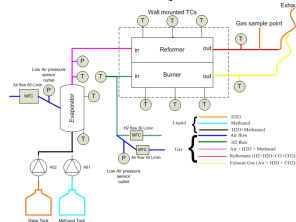


Figure 3: System diagram of a test setup for the methanol reformer

The start-up of the reformer is fast due to the low mass of the heat exchanger, but the temperatures can easily reach critical levels if the combustion process of hydrogen is not carefully controlled. As soon as the fuel is introduced, hydrogen is produced and the burner heat should be balanced to match to inlet fuel flow. Temperature measurements directly on the heat exchanger reveals a temperature gradient through the length of the reformer, which at low fuel flows could result in performance losses.

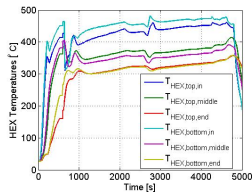


Figure 4: Typical temperature development during start-up and operation of the reformer.

"Rapid reformer start-up due to low thermal mass"

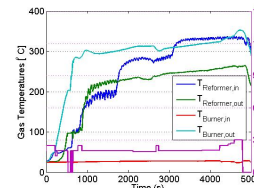


Figure 5: Temperatures of the reformer in-/and outlets. The oscillations in the reformer inlet temperature is due to a dead time.

When controlling the temperature of the evaporator with a standard PI feedback control, initial experiments point towards the presence of a significant dead time, which requires a more complex control strategy for precise temperature control. In other of the control areas in the system, this phenomena occurs and must be compensated for steady control of the temperatures.

"A model based control strategy can compensate for dead-time occurrence"

Different tests with fuel flow changes are made to reveal the dominating reformer dynamics, including the effects on the outlet gas composition.

Conclusions

The construction of the methanol reformer system illustrated in figure 3, has resulted an initial test and verification of using a catalyst coated heat exchanger as a methanol reformer.

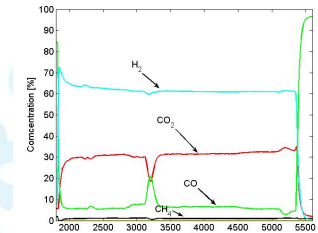


Figure 6: Gas composition during initial test. Notice the sudden change in CO and CO₂ when making a dramatic change in fuel composition.

The following conclusions were made while experimenting with the system, and fuelling it in different ways:

- Fast start-up with catalytically combusted hydrogen.
- Complicated temperature control due to dead-time.
- High CO content in reformat gas (5-6%)

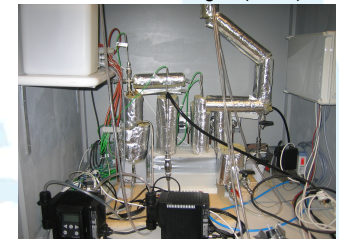


Figure 9: Picture of the experimental setup, showing the two black dosage pumps and the insulated pipes to and from the reformer.

The conclusions and experiences made during these initial experiments, have given much knowledge for the further testing of this reformer type. Before using the reformat gas in a HTPEM fuel cell stack, the CO content must be lowered considerably. Different approaches can be evaluated including raising the steam-to-carbon ratio, which could fuel the water-gas-shift reaction in the reformer to convert more CO into hydrogen or raising the overall reformer temperature, increasing the activity of the water-gas-shift process. A Smith-Predictor can be implemented to avoid problems with dead-time.

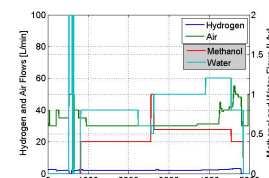


Figure 7: Fuel and burner flows in the reformer during initial testing.