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DEVELOPMENT OF AN AUTONOMOUS TRANSPORTABLE SOFC SYSTEM OPERATING ON C-BASED FUEL

THE LILITH SYSTEM

Schlussbericht

Ausgearbeitet durch

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Abstract

The aim of the project is to adapt a prototype portable SOFC system to the requirements of demonstrator for educational institutions as niche market. This involves on the one hand stable operation of the unit with reformed fuels, on the other hand the integration and control of auxiliaries such as fan and visualization. The result is aimed to be a practical communication vector, letting people touch SOFC technology.

As intended, 2 redesigned systems have been realised and mounted. While design simplification allowed an easier construction of the units, more technical challenges than anticipated were encountered on the level of thermal management. The re-designed thermal system did not improve the thermal management to the level expected. Eat transfer to the stack chamber was on the lower limit, leading to rather high exhaust temperatures and also affected stack performance and robustness. Reforming of methanol worked to satisfaction on the short term, long term data have not been obtained to date. Electronic controls, visualisation and auxiliaries have been elaborated based on the given specifications, but could not be validated on the complete system within the project time-frame.

After a major personnel change within HTceramix, it is intended to pursue the activity next year with a new team.

1. Ausgangslage

A first portable system prototype has been elaborated, able to operate in lab environment and demonstrating base function. The aim of the project is to improve the base system prototype to fulfill the requirements of educational institutions as niche market. This involves on the one hand stable operation with reformed fuels, on the other hand integration of auxiliaries such as fan, visualization and controls. The challenge is basically to integrate all infrastructures available in a laboratory in components of limited size and still sufficient performance. The aimed result would be a practical communication vector, letting people touch SOFC technology.

2. Ziel der Arbeit

The aim of the project is to improve the base system prototype to fulfill the requirements of educational institutions as niche market. In order to comply with those requirements, following elements are required:

- more robust, simplified thermal system
- stable operation with reformed fuels
- development and integration of auxiliaries such as fan, visualization and controls.

The specific goals are: Building 2 additional self-sustaining autonomous SOFC system (one for demonstration at HTc and one for EIVD)

- System surface temperature of system approximately 100°C .
- Exhaust gas temperature approximately 400°C .
- System weight about 10 kg for the core fuel cell system and 15 kg for the complete unit .
- Operated on commercial C-based fuel, either NG, LPG or ethanol, in commercial quality .
- Start-up time below 1 hour to reach more than 100W power .
- Stable operation at 150 W output power for 24 hrs at above 27% stack efficiency .
- Possibility of at least 3 thermal cycles (start, stop) .
- Price range between 25’000-30’000 CHF

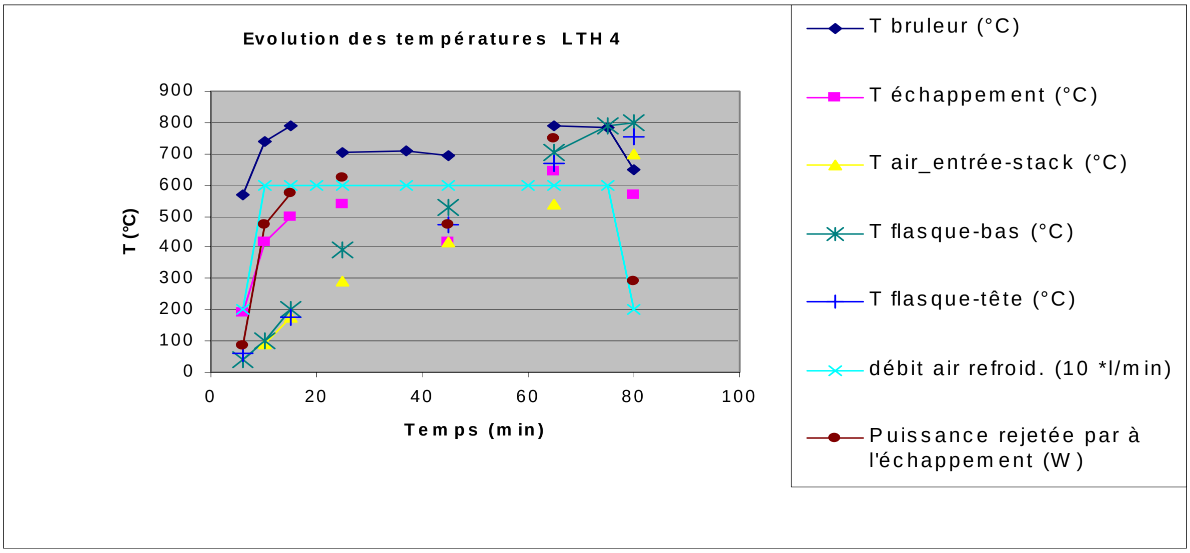
4. Ergebnisse

Based on the prototype system, design adaptations and simplifications have been done in order to reduce construction costs and to integrate commercial parts, i.e. the burner. Two additional units have been realised and tested. Following results have been achieved:

Thermal system

Preliminary thermal tests showed that a sufficiently rapid and efficient heating of the stack chamber could not be achieved with the commercial burner. The temperature in the burner chamber raised rapidly but the heat transfer to the stack chamber was insufficient. As a result, the temperature inside this latter chamber remained below 500°C and the exhaust temperature was too high. Only minor improvement could be obtained using the commercial burner. Finally, the commercial burner was re-placed by the previous type. This allowed a better heat transfer from the burner chamber to te stack chamber. This configuration was used for the stack test:

The first graph summarises the behaviour of the fuel cell during the first 80 minutes. The parameters (T_burner = Tbrûleur, T_ exhaust = T échappement, Ttop flange = T flasque tête, Tbottom flange = T flasque- bas, Tair stack-inlet = T air entrée-stack, air cooling flow rate = débit air refroid., Power at the exhaust = Puissance rejetée à l'échappement) present the evolution of the system.



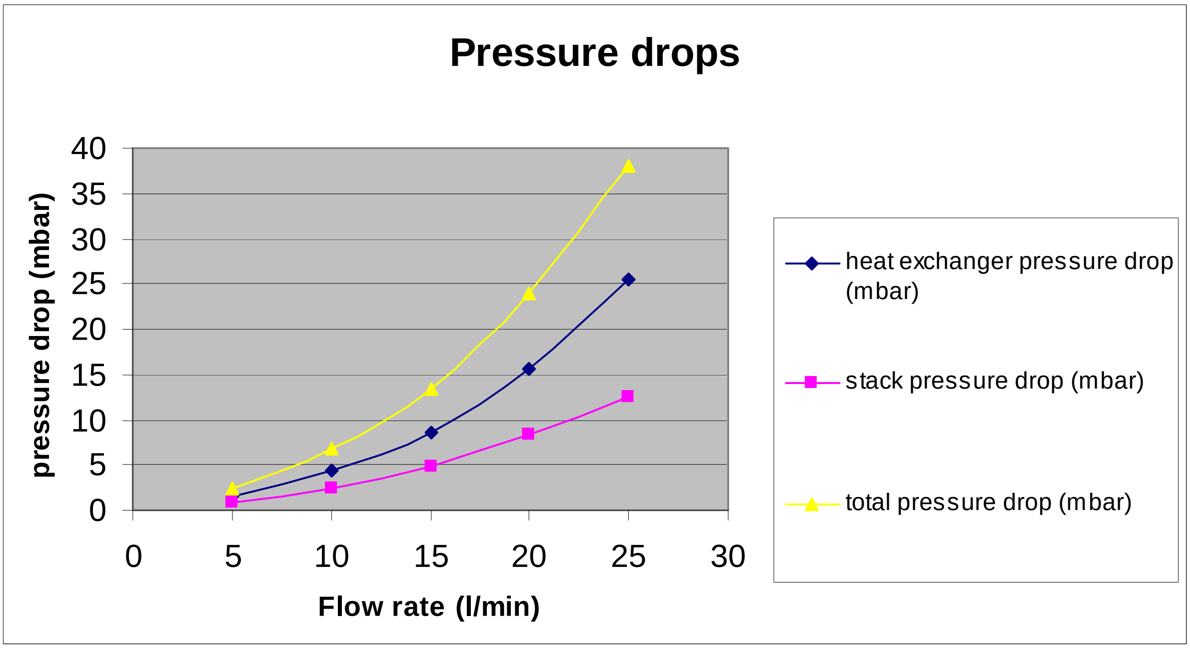
Graph 1: Evolution of temperature profile in the fuel cell

As we can see in the graph above, the top and bottom flanges are at a temperature of 700 (°C) after 60 minutes and 800 (° C) after 80 minutes. The burner has been stopped at 75 minutes. The temperature difference between the top and the bottom flange is less than 50 degrees and even decreases to less than 40 degrees when stopping the burner. This temperature homogeneity is judged acceptable for proper stack operation.

An amount of 60 (l/min) of air is injected in the burner chamber in order to heat the fuel cell upstream. As we can see on the graph the power rejected at the exhaust during the heating (temperature*Cpair*air flow rate) is about 600 (W) with a maximum of 760 (W) at the 65th minute. This shows that the thermal power of the burner is still not sufficiently transferred to the stack chamber but gives raise to a quick temperature increase to 800 °C in the burner chamber.

With an air inlet of 700 (°C) at a stack temperature of 800 (°C), the air heat exchanger is working properly with this amount of air (10 l/min) but might be insufficient for a 250 (W) stack, requiring 20 (l/min).

The pressure drops of the air heat exchanger and stack measured at 22 (°C) are represented in graph 2.



Graph 2 : pressure drop at 22 °C: heat exchanger, stack and total.

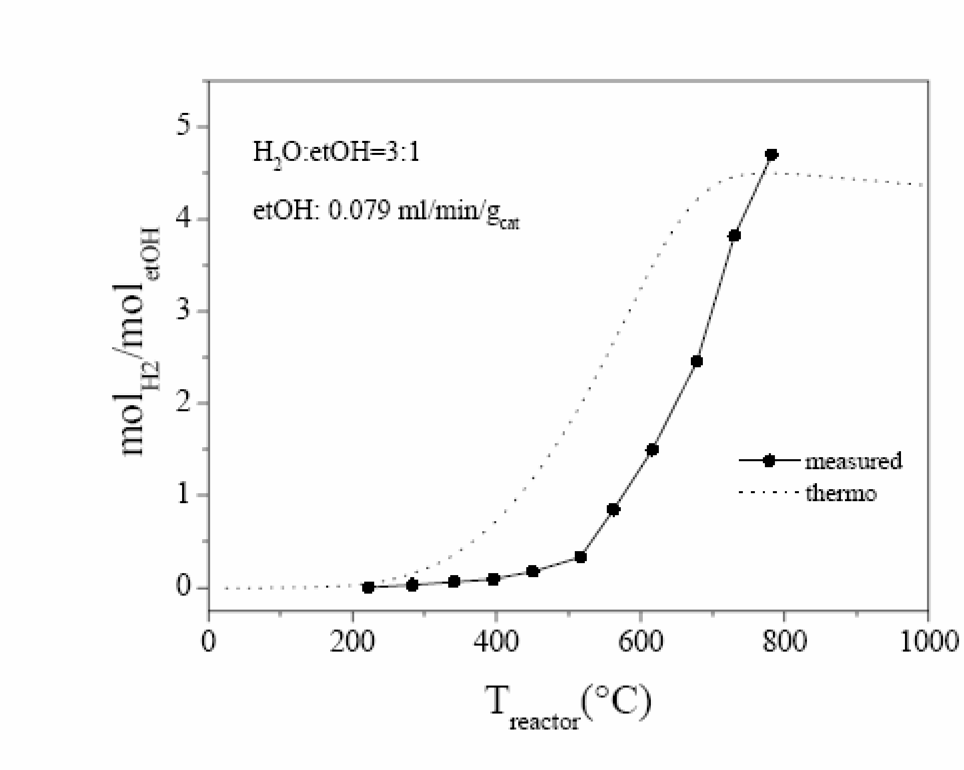
Stack

The power of the stack was limited to 46 (W) whereas 120 (W) were expected. The reason is a broken cell within the stack that increased dramatically the internal resistance of the stack. Post-mortem analysis showed that this broken cell was entirely broken and partly re-oxidised, indicating a break during operation. It explains also probably the reason why the power was decreasing minutes after minutes.

For further improvements, a more robust stack design has to be considered, i.e. increased mechanical resistance of the cells and possibly recuperation of the unused fuel. Of course, latter will also affect the thermal management of the system. SOF-CH project…

Reformer

The reformed methanol (after the reformer) has not been analysed in the system so far but seemed to be appropriate for this experiment. No carburisation was detected in post-mortem analysis. Preliminary tests indicated a sufficient operation on methanol.



Graph 3: Test of reformer catalyst.

Auxiliaries

Controls have been elaborated in order to control stack temperature, air flow in stack, fuel flow, implementing a 12V battery to control start-up. Stack current, power and several temperatures can be indicated.

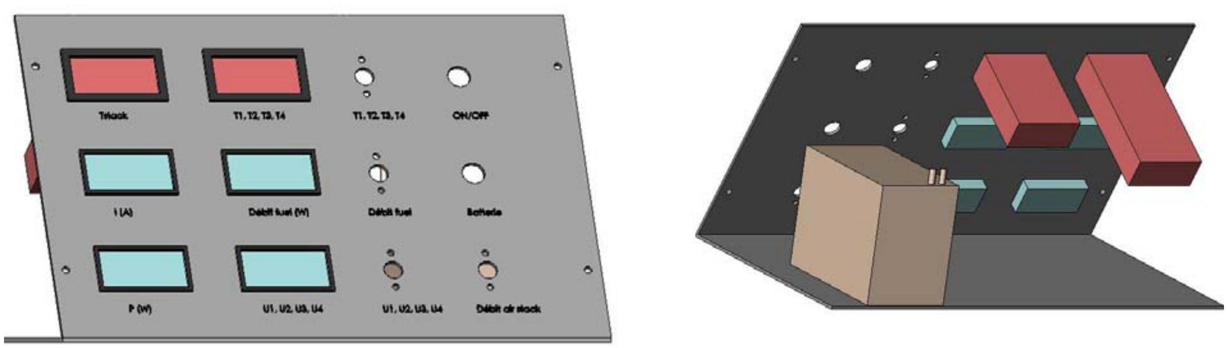


Figure 1:Front and back view of the control board allowing to control the system.

Complete system integration

The state of the system has not allowed a complete integration with controls and auxiliaries. Operation with dummy stacks and further robustness in thermal management and stack performance are required for the validation work.

5. Diskussion

The external system temperature, start-up time and weight criteria were achieved within the project, while the other technical objectives. The system could be operated on methanol fuel and should be in a state to run also on ethanol. The other objectives were not achieved, as the performance of the thermal management system is insufficient at its current stage.

The complexity of portable SOFC systems revealed unexpected challenges on the level of thermal management and stack integration. Simplified design and construction was achieved for system components, opening the possibility for low cost production of a limited number of units.

On the control level, relevant validation on the system level requires first a stable base system; the individual components have been elaborated and work to satisfaction.

6. Schlussfolgerungen

The challenge of a portable SOFC system has been underestimated in its complexity. The approach of building complete prototype units is as such defendable, but leads to long lead time for experimental validation of individual components i.e. the auxiliaries and visualisation system that could not be integrated with the current thermal system. Two thermal management systems have been realised and serve for further development. The systems heats up within the specified start-up time and is able to convert methanol fuel. The system weight also respects the specification. In order to reach the requirements of educational institutions, following elements need to be addressed in further work:

- Better heat transfer from the burner to the fuel cell (stack and walls)
- Better heat transfer between the hot air flow and air heat exchanger
- Reduced pressure drops in the air heat exchanger
- Simplified connecting (air and fuel tubes)
- Possible switch to cpox LPG (commercial fuel)
- More robust stack design
- Validation of auxiliaries and controls on complete system level

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