HT-PEM Fuel Cell System with integrated complex hydride storage tank

Report available on the web site: http://www.veu.de Project number: 247

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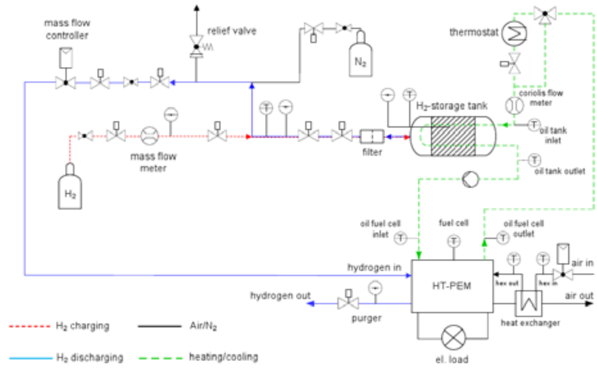
Introduction

Hydrogen storage is one of the major challenges encumbering hydrogen economy. There are three common techniques of hydrogen storage: pressurized hydrogen, liquified hydrogen and hydrogen reversibly chemisorbed or physisorbed (metal hydrides, MOF, carbon materials). A fuel cell system described here was developed and tested with a hydrogen storage tank based on the metal hydride sodium alanate ($NaAlH_4$) which was thermally coupled to a high temperature PEM fuel cell (HT-PEM). The fuel cell was fed by hydrogen desorbed from the storage tank while the fuel cell provided the reactor with the necessary heat for desorbing hydrogen. The main tasks carried out by the partners in this co-operation project were: ZBT has developed the HT-PEM fuel cell stack, MPI produced the metal hydride sodium alanate material and IUTA constructed and tested the hydrogen storage tank.

Experimental



Sketch of the test rig

Hydrogen storage tanks:

I. prototype

- m_{NaAlH4}= 67g
- x_{TiCl3}= 4 mol.-%
- ξ_{H2}= 3,35 mass.-%
- m_{H2}= 2,2g; V_{NH2}=24,5l
- Heat exchange: u-bends

II. prototype

- m_{NaAlH4}= 241g
- x_{TiCl3}= 4 mol.-%
- ξ_{H2}= 3,35 mass.-%
- m_{H2}= 8g; V_{NH2}=90l
- Heat exchange: oil in annulus, (+)coil

Final version

- m_{NaAlH4}= 2676g
- x_{TiCl3}= 4 mol.-%
- ξ_{H2}= 3 mass.-%
- m_{H2}= 80g; V_{NH2}=900
- Heat exchange: oil in annulus and coil

HT-PEM fuel cell:

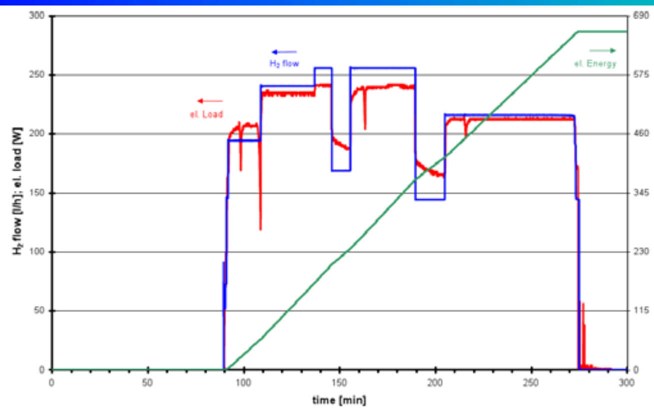
- 28 cells
- $P_{el.}$= 260W
- $t_{op.}$= 120-190°C
- $I_{max.}$= 21A
- A_{active}=50cm²
- $U_{open\ circuit}$= 25V

Sodium alanate ($NaAlH_4$) reactions:

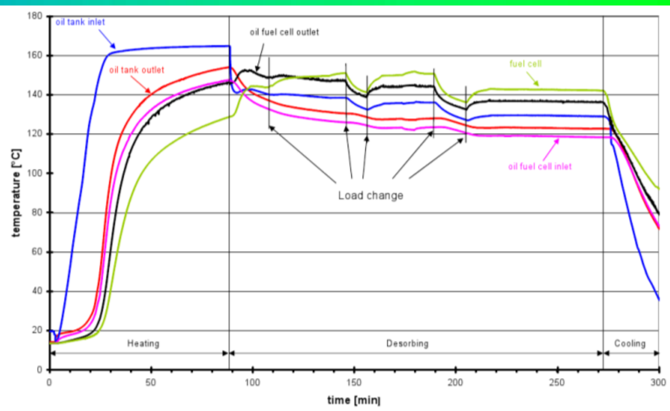
I) $NaAlH_4 \leftrightarrow \frac{1}{3}Na_3AlH_6 + \frac{2}{3}Al + H_2(\uparrow)$ 3,7 Mass.-% H_2

II) $\frac{1}{3}Na_3AlH_6 + \frac{2}{3}Al \leftrightarrow NaH + Al + \frac{1}{2}H_2(\uparrow)$ 1,8 Mass.-% H_2

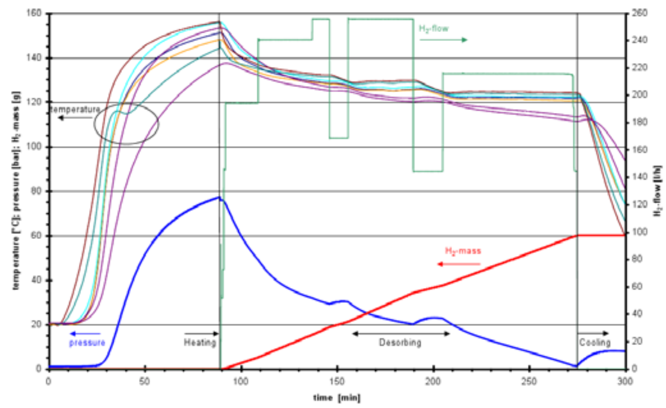
Results



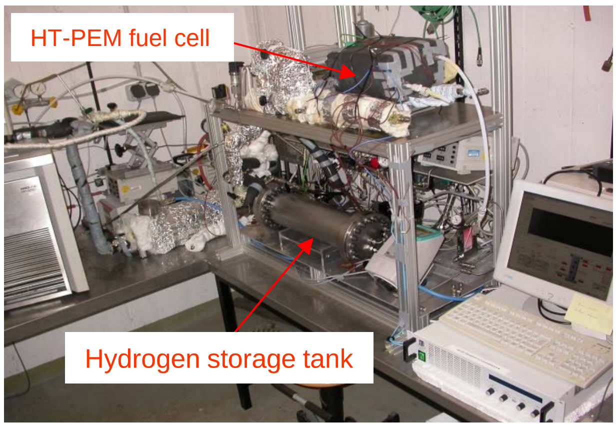
Load profile, hydrogen flow and cumulated el. energy



Oil and fuel cell temperatures



Parameters in hydrogen storage tank



Test rig: endversion of the hydrogen storage tank and HT-PEM fuel cell

Conclusions

A high temperature fuel cell was operated together with a hydrogen storage tank based on complex metal hydride sodium alanate. Both components were thermally coupled so the heat generated by the fuel cell was transferred to the sodium alanate in the hydrogen storage tank for desorbing hydrogen which was then supplied to the fuel cell. The system was operated at different current loads applied to the fuel cell. 2,24% of hydrogen content of the metal hydride could be liberated during 3 h (in comparison to 3% in the very first cycle). The generated electrical energy was 660 Wh. In future systems the heat losses in the thermal circuit have to be radically reduced. It can be improved by increasing the flow of the thermal fluid on the one hand and by increasing the heat transfer area on the other hand. But it should be kept in mind that the heat transfer resistance is primarily offered by the sodium alanate particles.

UNIVERSITÄT DUISBURG ESSEN

Verein zur Förderung der Energie- und Umwelttechnik e.V.

The research project no. 247 ZN of the research association VEU has been funded via AiF within the agenda for the promotion of industrial cooperative research and development (IGF) by the German Federal Ministry of Economics and Technology based on a decision of the German Bundestag.

Gefördert durch: Bundesministerium für Wirtschaft und Technologie aufgrund eines Beschlusses des Deutschen Bundestages

AiF Ideen eine Zukunft geben