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Operational Experience from a 5 kW$_e$ HT-PEFC System with Reforming of Diesel and Kerosene

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This contribution deals with fuel-cell-based auxiliary power units for the transportation sector. The reforming of diesel fuel and kerosene-based jet fuels opens the possibility of also using liquid fuels, which are stored onboard for traction, for the fuel cell system. Not only fossil-based conventional fuels, but also synthetic non-fossil-based fuels can be used in fuel cell systems to enable a sustainable fuel supply. The high-temperature polymer electrolyte fuel cell (HT-PEFC) technology offers system-level advantages under operation with reformate. The electrochemical performance of this fuel cell technology is not yet comparable with the state-of-the-art PEFC technology, but its CO tolerance is much higher (> 1 %). Furthermore, no difficult water management is necessary inside the stacks. These features allow system simplification because neither CO fine-cleaning nor external humidification equipment for the gases are necessary. Recently, Forschungszentrum Jülich developed an integrated HT-PEFC system for operation with diesel and kerosene. Considering the requirements of mobile applications, the fuel processor consisting of an autothermal reformer, a two-stage water-gas shift reactor, a catalytic burner and a heat exchanger was developed as a compact package. The fuel processor was combined directly with two HT-PEFC stacks. Additionally, the components were combined in such a way that the heat integration of the complete system allows self-sustaining system operation with no external sources of heat or electricity. This paper reports about the characterization of the complete system in the 5 kW$_e$ power class, including stack performance under fuel processor operation with different fuel qualities.

The system was designed with the aim of maximizing heat integration and minimizing the number of components. The reformer and the catalytic burner were equipped with internal heat exchangers. The reformate from autothermal reforming can be fed directly into the two-stage water-gas shift reactor without further treatment. Cooling between high- and low-temperature shift stages is maintained by liquid water quenching. The fuel processor is designed to deliver 1 % (vol.) CO at the outlet of the shift reactor. The reformate is subsequently cooled down to 160 °C. This is realized in a co-current heat exchanger cooled by cathode air before entering the stack. In this way, cathode air is also heated to the ideal operation temperature of the stack. The anode off-gas is fed into the catalytic burner and combusted there completely. The heat of combustion is recovered for educt conditioning for reforming. This is realized via the injection of cold water onto a hot surface in contact with hot off-gas from combustion on the other side. The resulting evaporated and slightly superheated steam is mixed with cold water to be evaporated and superheated to approx. 420 °C in the reformer heat exchanger before being introduced into the reformer mixing chamber. The oil-cooled HT-PEFC stacks were developed for operation with reformate coming from the autothermal reforming of diesel and kerosene. The stacks were built in a modular way with each short stack comprising 12 cells, each with an active cell area of 320 cm^2. Three short stacks were combined to make up a stack with 36 cells in total. Two such stacks were integrated into the system with 72 cells in total. Due to peripheral reasons, 70 of the 72 cells were equipped with membrane electrode assemblies. Commercially available phosphoric-acid-doped polybenzimidazole (PBI) membranes were used in the stacks. Further information on the HT-PEFC stack technology at Jülich is available in [1]. Information on the fuel processing reactors used in this system has been published in [2]. The system concept and results of subsystem experiments can be found in [3].

In the present work, the stacks and the fuel processor were combined for the first time in an integrated system. The system was operated with different fuel qualities, such as GTL kerosene and BTL diesel as synthetic fuels and Aral Ultimate Diesel as a fossil-based diesel fuel available at filling stations in Europe. The reformer was operated with fuel flow rates in the range of 1600-1800 g/h with molar O_2/C and H_2O/C ratios of 0.47 and 1.9, respectively. For cooling between shift stages, 900-1200 g/h water was added. The inlet temperature of cooling oil into the stack was 160 °C.

Successful and stable operation was demonstrated with all fuels used. The target electrical power of 5 kW was reached and even exceeded. The target H_2 utilization of 83 % was demonstrated. Additionally, the integrated system concept with heat recovery was validated, showing self-sustaining system operation at the design point.

As an example, Fig. 1 shows performance data of the stack operated with BTL diesel in the system. According to the figure, no performance loss was observed during this experiment lasting approximately 42 hours. The maximum power in this experiment of 4.8 kW was reached at a current density 450 mA/cm^2. Further results from operation with different fuels will be presented during the meeting.

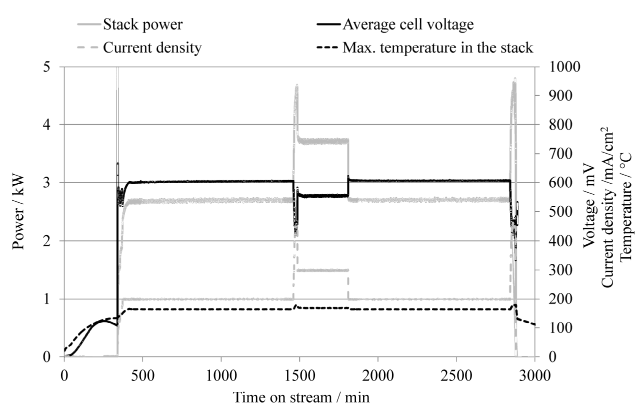

Figure 1: Performance data of the HT-PEFC operated with reformate from BTL diesel.

References:

[1] H. Janßen, J. Supra, L. Lüke, W. Lehnert, D. Stolten, International Journal of Hydrogen Energy (2013), http://dx.doi.org/10.1016/j.ijhydene.2013.01.127.

[2] J. Pasel, R.C. Samsun, R .Peters, D. Stolten, Energy and Fuels (2013), http://dx.doi.org/10.1021/ef301976f.

[3] R.C. Samsun, C. Wiethege, J. Pasel, H. Janßen, W. Lehnert, R. Peters, Energy Procedia 29 (2012) 541-551, http://dx.doi.org/10.1016/j.egypro.2012.09.063