Investigation of Load-Temperature Balancing of the Operation of Commercial HT-PEMFC Stacks with Reformed Logistic Fuels

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Abstract: Fuel cells can be a relevant to address low signature power generation demands in military operations. The requirement to operate on logistic fuels is a significant obstacle in achieving this goal. Fuel cells operating at higher temperatures are known to be less prone to poisoning by impurities like CO and H_2S. High temperature polymer electrolyte fuel cells operating at 160 – 180 °C offer sufficient resistance against such impurities avoiding other issues arising from still higher operating temperatures of solid oxide fuel cells. Military power sources often need to operate at low partial load. As the operation of fuel cells at reduced load increases the conversion efficiency, less rejected heat is available to maintain the stack operation temperature. To evaluate this operating condition test were performed on commercial Serenergy S165L-35 stacks analysing the heat rejection at different loads and temperatures. It was found that for reduced loads the stack temperature needs to be reduced to temperatures as low as 135 °C. Still a stable operation with pure hydrogen as well as with surrogate reformate was possible.

In total the results proved that low level part load operation of HT-PEMFC is viable not providing obstacles for a military use. In the systems design the water management of the fuel gas processing needs careful attention.

Keywords: fuel cell; HT-PEMFC; logistic fuels; partial load

Introduction

Fuel cells can continuously provide electric power by conversion of several different fuels. As this happens with low noise and IR signatures, fuel cells are an interesting alternative for military application requiring low signatures and needing long operating times which cannot be covered by batteries easily. If logistic fuels are used, the fuel stream resulting from the down stream fuel processing will contain CO and may contain H_2S. Both substances act as poison for the fuel cell electrode. Thereby the strength of the effect depends on the operating temperature. As was shown [1–3], high temperature polymer electrolyte fuel cells operating at 160 – 180 °C offer sufficient resistance against such impurities avoiding other issues arising from still higher operating temperatures of solid oxide fuel cells. A second prerequisite to the use of fuel cells as military power source is now the ability to operate at low partial load conditions, as military power sources are usually over dimensioned. Part load operation of fuel cells increases their expected lifetime and efficiency and thus decreases more than linearly the available rejected heat. This leads to the questions at which operation temperatures HT-PEMFC can function at reduced load and if a stable operation still is possible. Here the results of an experimental investigation of these questions are presented.

Experimental set-up

Experiments were carried out on commercial HT-PEMFC stacks S165L-35 by Serenergy, Aalborg (DK). These stacks have a geometrical cell area of 165 cm^2 and 35 cells. The rated power with steam reformed methanol is 1.5 kW @ 400 mA cm^2. The stack was tested in a Greenlight FCATS G40 test rig specially designed for the test of HT-PEMFC in combination with online mixed surrogate reformate. Cooling as well as heating of the stack if required are performed with a closed Triethyleneglycol cycle. The control of the stack temperature is done by regulating the coolant outlet temperature by varying the coolant inlet temperature and the coolant flow. The heat performance of the stack can thus be calculated from the temperature difference between coolant inlet and coolant outlet using the following equation:

$$P_{therm} = \left(T_{cool_{in}} - T_{cool_{out}}\right) \cdot \frac{dm_{cool}}{dt} \cdot cp_{cool} \qquad (1)$$

Hereby negative values indicate heat rejection from the stack whereas positive values indicate heat delivery to the stack. A value of zero signifies, that the stack temperature is maintained without heat exchange via the coolant circuit. In a series of test P_{therm} was measured as function of load with the coolant outlet temperature set-to different values. This was used to determine the operating temperature range. Subsequently this temperature range was also used for test with surrogate reformed NATO-F34 (JP-8).

Results

In a first tests the effect of different stack operating temperatures on the stack performance was evaluated. It was found that a larger reduction of the stack temperature will reduce the achievable performance but that a minor reduction by 5 K has not a significant influence.

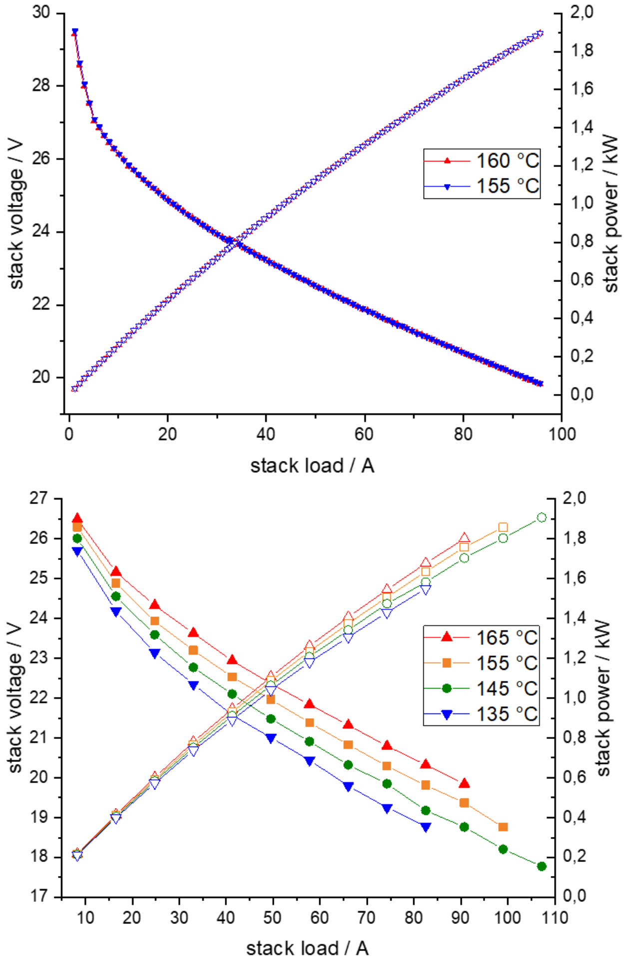

Figure 1. Effect of a reduction of the stack temperature by 5 K (upper) and by 30 K in 10 K steps (lower).

For the iV-curves in figure 1, the temperature of the stack, i.e. the temperature of the coolant outlet was maintained at the listed constant value. As the reject heat varies with the load, this requires that the cooling adjust itself to the load by reducing coolant inlet temperature. This can be seen in figure 2.

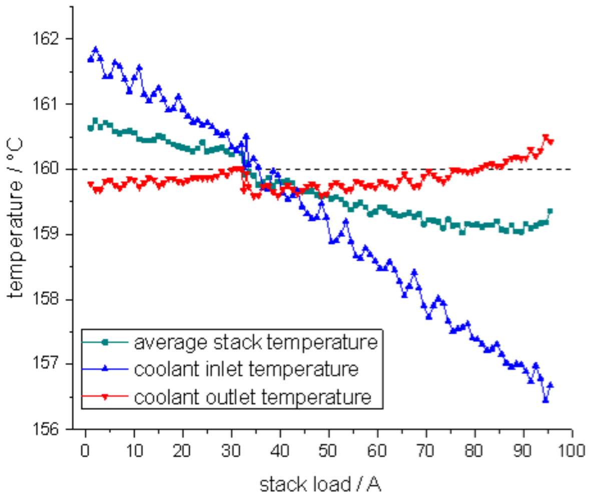

Figure 2. Load dependents of coolant in, coolant out and average stack temperature for a coolant out set value of 160 °C

The difference between coolant inlet and outlet temperature indicates the heat exchange via the cooling circuit with positive values signifying a heat-up take by the stack. As can be seen in figure 3 at a stack temperature of 160 °C this I the case until about 40 A load.

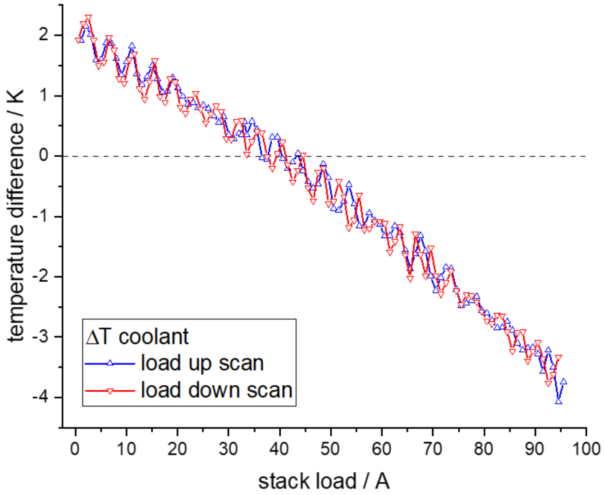

Figure 3. Load dependence of the difference between coolant inlet and outlet temperature for a set value of 160 °C

If the stack temperature is reduced, the load up to which a heating of the stack is required reduces as well (cf. Figure 4)

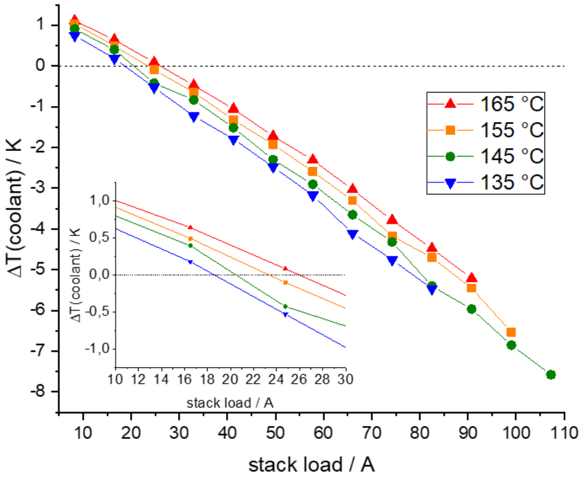

Figure 4. Load dependence of the difference between coolant inlet and outlet temperature for a set values between 135 °C and 165 °C

At low loads the stack should therefore preferably be operated at a reduced temperature. As the operating temperature also influences the tolerance against fuel impurities it was investigated if operation at reduced temperature with surrogate reformed NATO F34 fuel (JP-8) is possible. For that the stack was operated with a surrogate reformate with a dry gas composition of 55 vol.% H_2, 0.5 vol.% CO, 5 ppm$_v$ H_2S balance N_2 and a dew point of 55 °C. The iV-curves in figure 5 reveal that at high load the standard operating conditions with $\lambda_A = 1.4$ and an operating temperature of 165 °C are not sufficient to meet the target of achieving 90 % of the rated power of 1.5 kW for operation with steam reformed methanol. To accomplish this either the anode stoichiometry or the operating temperature needs to be increased. At low loads the raise of operating temperature to 175 °C has no effect.

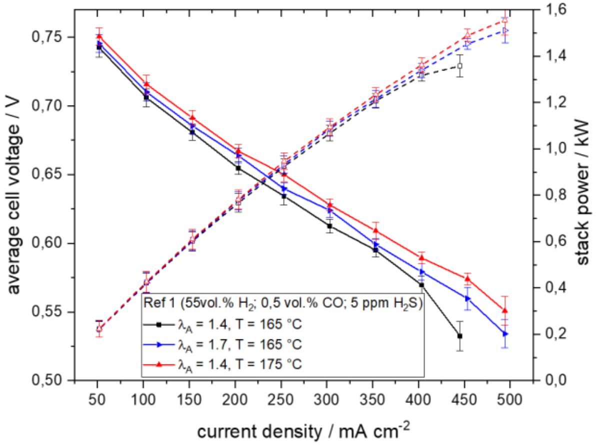

Figure 5. iV curves fo operation with surrogate reformate

Therefore, it was tested if at such low loads also a reduction of the operation temperature is possible. As can be seen in table 1 and figure 6 that can be confirmed.

Table 1. Operation conditions for five different loads

Point	**P_{el} [kW]**	**load [%]**	**i [mA cm^{-2}]**	**U_{cell} [V]**	**T_{op} [°C]**
Full load	1.4	100	400	0.61	175
High load	1.07	76.7	300	0.62	165
Medium load	0.762	54.5	200	0.66	165
Low load	0.404	28.9	100	0.70	155
Minimum load	0.211	15.1	50	0.73	155

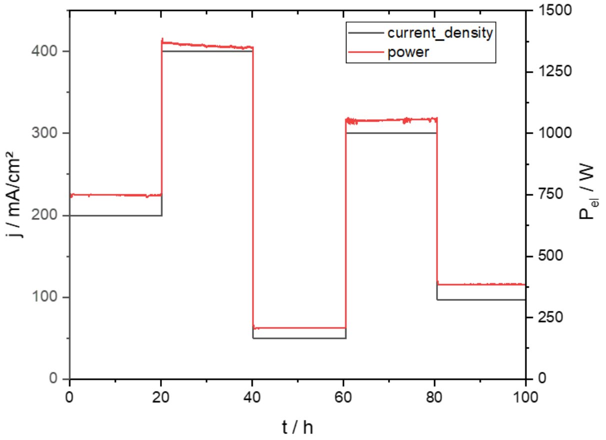

Figure 6. Experimental validation of load point

Conclusions

Due to increased efficiency the rejected thermal power of the stack at low loads is much lower. This requires a reduction of the operating temperature. Tests with surrogate NATO-F34 containing CO and H_2S have shown, that at low loads operation at temperatures as low as 135 °C is possible even with that fuel.

References

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