Catalytic burner with internal steam generation for a fuel cell based auxiliary power unit for middle distillates

J. Meißner[1*], R.C Samsun[1], J. Pasel[1], R. Peters[1], D. Stolten[1]
[1]*Forschungszentrum Jülich, Institute of Energy and Climate Research – Electrochemical Process Engineering, Juelich, 52428, Germany*
**corresponding author: j.meissner@fz-juelich.de*

Introduction

For the operation of a fuel cell based auxiliary power unit (APU) with a logistic fuel such as diesel or kerosene the fuel is converted by autothermal reforming (ATR) into a hydrogen-rich gas mixture. The product gas must be conditioned to meet the demands on the gas quality for the operation of a polymer electrolyte fuel cell (PEFC).

A catalytic burner (CAB) was developed to convert the anode off-gas of a PEFC. In addition, when by-passing the PEFC in ATR part-load the CAB must be able to convert the un-converted reformate completely (by-pass mode). Furthermore, at all load levels of the APU, up to 82 % of the ATR water demand has to be provided as superheated steam by the CAB [1].

Materials and Methods

For the operation of the CAB the commercial catalyst HiFUEL AB10 coated on a 400 cpsi ceramic monolithic carrier from Johnson Matthey Plc. was used. The catalyst was dimensioned not to exceed a GHSV = 50,000 h^{-1} in by-pass mode. From the top of the reactor water is sprayed onto a hemispherical surface. The CAB-fuel (anode off-gas/reformate) is premixed with air and added from below, homogenized and combusted on the catalyst. The resulting hot off-gas heats the spray area from below. The water droplets hitting the hot surface begin to evaporate. The steam/water mixture flows into an outer concentric annular gap and is evaporated further and superheated in co-current flow to the hot off-gas [1]. **Table 1** gives typical CAB fuel gas compositions.

Table 1. Typical CAB fuel gas compositions.

	Reformate, 5 % CO	**Reformate, downstream WGS**	**Reformate, downstream PrOx**	**PEFC anode off-gas**
H_2 [mol.%]	26.6	31.5	30.9	8.2
CO [mol%]	5.0	0.5	< 0.01	0.003
CH_4 [mol.%]	0.28	0.29	0.29	0.37
H_2O [mol.%]	25.3	21.2	21.3	28.3
CO_2 [mol%]	11.4	16.1	16.2	21.5
Ar [mol%]	0.4	0.4	0.4	0.5
N_2 [mol.%]	31.2	30.1	31.0	41.2

Results and Discussion

Figure 1 shows the temperatures of an experiment with typical operations points of the CAB in an APU system. The gas clean-up units are not able to deliver the gas quality as required for the operation of a PEFC immediately after start-up of the ATR. Hence the CAB has to ignite with a reformate at an elevated CO concentration of 5 mol.% (**Table 1**). The ignition of the reaction was conducted at an air ratio of $\lambda = 1.5$, and increased after ignition to $\lambda = 4.25$. Already 20 s after the ignition 82 % of the ATR water demand was evaporated and superheated by the CAB. The CO content in the feed gas to the CAB was first reduced to 0.5 %, then to 40 ppm. Thereafter the CAB was switched to normal operation followed by two load increases up to nominal load; finally it was shut-down.

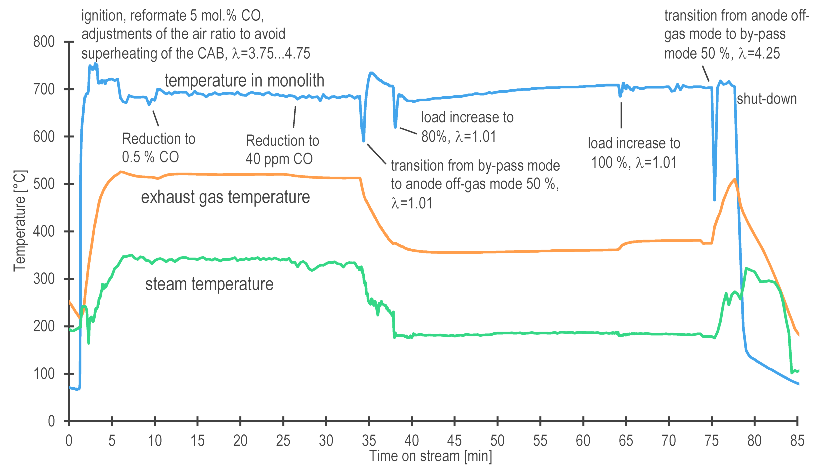

Figure 1. Temperatures in the CAB. Ignition in by-pass mode with reformate containing 5 % CO, stepwise reduction of the CO-concentration, load changes and shut-down. [2]

Significance

The use of an appropriate catalyst permits a fast ignition of the CAB with a diesel reformate at an elevated CO-concentration. At all load levels complete conversion of the combustible compounds can be ensured, while superheated steam according to the demand of the ATR is generated. For a period of 6 min after the shut-down, the CAB is able to provide steam with a temperature of > 120 °C for flushing the downstream reactors. A lightweight construction enables a power density of 6.3 $kW_{th,\ APU}/l$ of the CAB. The reactor fully complies with the requirements placed upon it by a PEFC-based diesel APU for mobile application.

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References

1. Meißner, J.; Pasel, J.; Samsun, R. C.; Scharf, F.; Wiethege, C.; Peters, R. *Int J Hydrogen Energ* **2013**, DOI 10.1016/j.ijhydene.2013.05.167.
2. Meißner, J.; Pasel, J.; Samsun, R. C.; Peters, R.; Stolten, D. Start-up and load-change behavior of a catalytic burner for a fuel-cell-based APU for middle distillates, Appl Energ, submitted 2013.