Compact reformer/burner module for small scale LPG powered fuel cell APUs

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Introduction

A fuel cell auxiliary power unit (APU) using liquefied petroleum gas (LPG) for mobile applications is currently being developed at the Centre for Fuel Cell Technology (ZBT). The integrated fuel processor consists of a reformer/burner module and a CO-purification module producing 1 $kW_{th,H2}$ at nominal load.

The innovative reformer/burner module includes a water evaporator, several heat exchangers and as its main part a combined steam reformer and catalytic burner reactor based on metallic structures. The burner fulfils three tasks: It functions as a start up burner, as an anode-offgas burner and as a supplier for the necessary steam reforming reaction heat.

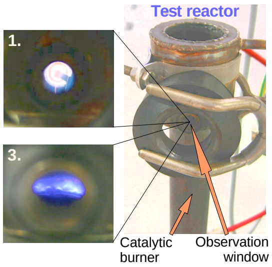
Start up concept

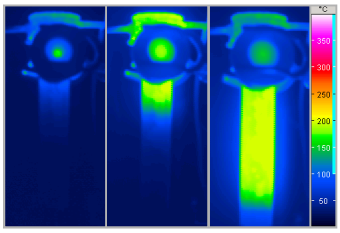
At ambient temperature the catalytic burner does not produce any heat due to the ignition temperature of the LPG/air mixture of 250 °C in presence of an adequate catalyst. For the necessary preheating no hydrogen or anode-offgas is available and no electrical heating should be utilized.

As solution to this problem a new method for reformer cold start up was developed by simply employing a sparking plug at the outlet of the catalyst burner and operating the catalytic burner as flame combustor.

Start up sequence

1. Initial ignition of LPG/airmixture by the sparking plug at burner reactor outlet
2. Monolithic structure functions as a flow distribution plate and as flame barrier
3. A stable flame appears at burner reactor outlet
4. Burner reactor structure is heated up in counter flow direction
5. Start of catalytic oxidation by reaching activation temperature
6. End of flame combustion due to upstream catalytic conversion of burner feed

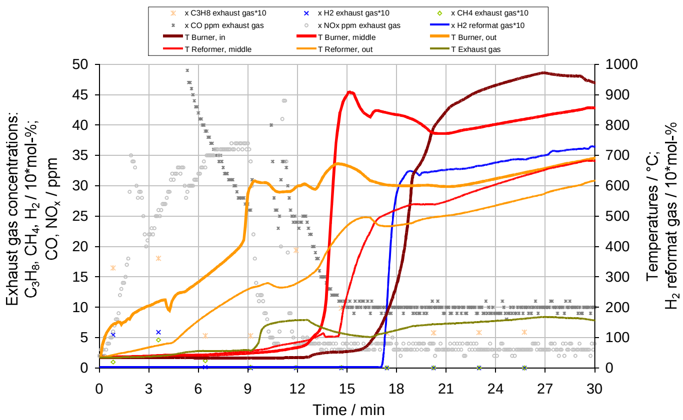




Cold start up is demonstrated with a non insulated test reactor. The three sequences ignition and flame combustion at the burner reactor outlet after 2 minutes, the transition to catalytic oxidation after 9 minutes and the complete catalyst activation after 14 minutes are visualized with IR-camera pictures.

The following start up procedure tests were conducted with the reformer/burner module.

Start up procedure



- Ignition and stable flame after 3 minutes
- Transition from flame to catalytic combustion after 9 minutes
- Supply of air after 9 minutes and an air/water mixture after 13minutes to the reformer
- Propane and water supply to the reformer after 17minutes
- Hydrogen concentration of 65 % 19 minutes after start up

During the periods of ignition, formation of stable flame combustion and transition to catalytic oxidation exhaust gas emissions are caused by air ratio values 0.9 < λ < 1.1 and partly instable flame combustion due to the effect of flame failure at cold walls. Subsequent to the activation of catalytic combustion concentrations decrease to 0.6 % C_3H_8 and below 10 ppm CH_4, H_2, NO_x and CO.

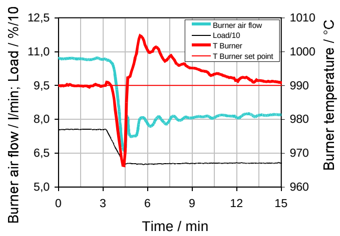
Automated operation

Due to the following coupling with the fuel cell an automation has been developed for the operation of the reformer/burner module and the CO-purification module respectively. The load is controlled by the supply of the reformer propane, including a fixed steam-to-carbon ratio S/C. Furthermore, a temperature regulation for the reformer/burnermodule was designed whereas the:

- burner propane flow is controlling the reformer temperature
- burner air flow is controlling the burner temperature

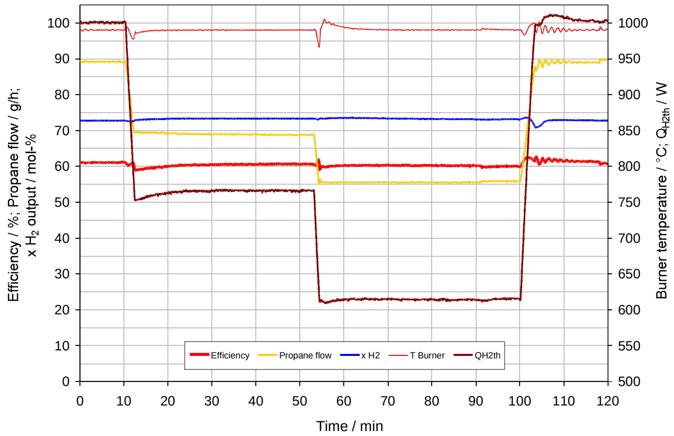
For the temperature regulation PID controllers including the flow ranges as boundary conditions have been implemented to the system control. The right diagram shows the burner temperature regulation at a load change from 75-60 % load. Observable are:

- a short time of transient effect
- a smooth approach to the desired burner temperature



The following data of dynamic operation tests were performed with the complete fuel processor. The efficiency is calculated based on the following definition including an assumed fuel utilization of the fuel cell FU of 70%.

$$\eta_{mobile\ gas\ processor} = \frac{\dot{n}_{H_2,out} \cdot H_{low,H_2}}{\dot{n}_{C_3H_8,in} \cdot H_{low,C_3H_8}} \cdot FU$$



Results of dynamic operation in the load range from 60 - 100%:

- fast transient response of the reformer/burnermodule at a load change velocity of 2 W/s
- constant hydrogen power output
- steady efficiency above 60 %
- exhaust gas composition: < 5 ppm CO, H_2, NO_x and 0.2 % CH_4 and 0.3 % C_3H_8

Summary

The proceeding development of ZBT´s LPG based APU led to a new start up method and an optimized automated operation of the reformer/burnermodule with the following features:

- Development of a start up procedure with a sparking plug and the single catalytic burner operated in flame and catalyticmode
- Start up time < 20minutes
- Automated operation of reformer/burnermodule andmobile gas process
- efficiency above 60 % during dynamic and steady state operation
- Patents are currently pending

Further development

The start up procedure still has to be optimized concerning reduction of emissions and duration. Furthermore the requirements for heating up the downstream CO-purification module and fuel cell have to be considered.

Acknowledgements

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