AUTOTHERMAL REFORMING OFJP8 IN A CATALYTIC FINS REACTOR

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SUMMARY

On site Hydrogen generation via Fuel Processors is expected to become a wide spread technology for a variety of end users such as portable power, transportation, auxiliary power and ICE combustion enhancement. Reforming of liquid fuel has become important for a variety of applications such as remote power production via PEMFC and SOFC, ICE combustion enhancement with syngas. To understand the performance issues associated with logistical fuel reforming a series of experiments were performed on a finned wall reactor, for steam to carbon (S/C) ratios between 1.6 and 2.8 and oxygen to carbon (O/C) ratios between 0.8 and 1.2. The reactor, preheated with air and steam from the feed delivery system, lit off and performed auto-thermally without the need for external heating. Significant CO2 production was detected during catalyst lightoff transitory, which sheds light in the lightoff mechanism for JP8 Autothermal Reforming.

MOTIVATION

Short-term Market:
Syngas production for commercially viable applications:
•ICE combustion enhancement for cleaner, more efficient operation,
•pre-reforming for SOFC fuel cells
•High purity Hydrogen production for PEM fuel cells (stationary, remote, transportation, military)
Long-term Market:
Fuel processors for Hydrogen vehicles:
•**Centralized** at gas stations (enabling carbon capture and storage(CCS))
•**On board**, coupled with Air Capture technology (on-board CCS is unfeasible: every kg of Gasoline used produces ~3kg of CO_2 !!

FUEL PROCESSING FOR PEMFC

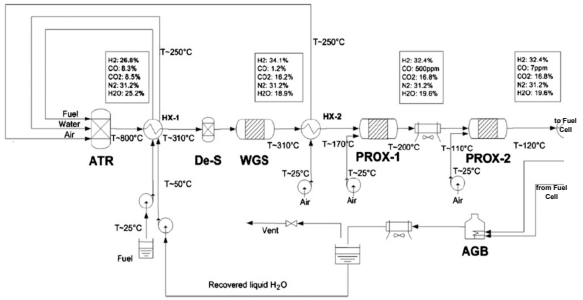


Figure 1: A Fuel Processor for PEM Fuel Cells is depicted, showing product stream concentration for each conversion step as generated by past testing, along with operating temperatures

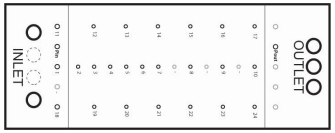
EXPERIMENTAL

Reactor Design:
•10 kW thermal input
•24+24 catalyzed interdigitated fins (300 x 12.6 x 3 mm each)
• Total kinetic volume 240 cc

Reactor equipped with 24 temperature ports: 10 for central longitudinal, 10 for skin and 4 lateral longitudinal temperatures. Fin TC are located 1 mm within the fin wall.

Catalyst:
•Double layer BASF washcoat
• Pt-Ru, Rh-Pt on Alumina

•Re = 100-200 (laminar flow)
•GHSV = 20,000 -40,000 h^{-1}



AUTOTHERMAL REFORMING REACTOR

$$C_{11}H_{21} + 11\ H_2O \rightarrow 11\ CO + \tfrac{21}{2}\ H_2O \quad \Delta H_{f,298} = 1,694\ kJ/mol \quad \text{Steam Reforming}$$
$$C_{11}H_{21} + \tfrac{11}{2}\ O_2 \rightarrow 11\ CO + 11\ H_2 \quad \Delta H_{f,298} = -966.8\ kJ/mol \quad \text{Partial Oxidation}$$
$$C_{11}H_{21} + \tfrac{43}{2}\ O_2 \rightarrow 11\ CO + 11\ H_2 \quad \Delta H_{f,298} = -6,627\ kJ/mol \quad \text{Total Oxidation}$$
$$CO + H_2 \rightarrow CO_2 + H_2O \quad \Delta H_{f,298} = -41.2\ kJ/mol \quad \text{Water Gas Shift}$$

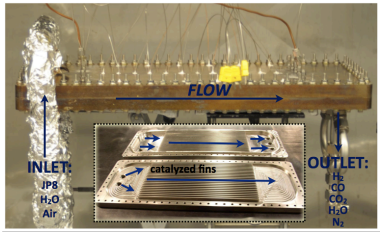


Figure 2: ATR reactor is shown, with feed manifold and thermocouples. Superimposed picture shows the open reactor which consist of two complementary parts. The two parts are bolted together such that fins interlock leaving an 1.25 mm wide flow channel.

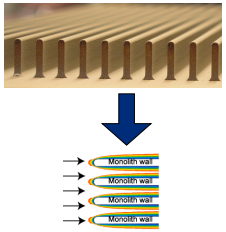


Figure 3: Magnification of catalyzed fins. Flow through reactor is laminar with boundary layer buildup, similar to flow through a commercial monolith,, shown here in a FLUENT simulation.

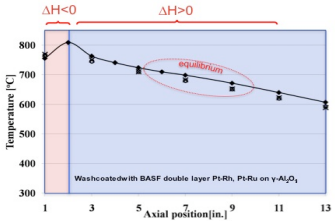


Figure 4 : Temperature profile for the ATR reactor at nominal conditions of S/C=2 and O/C=1. Thermodynamic equilibrium composition is reached in mid-reactor.

- ΔH<0: Net positive heat production by predominant exothermic reaction
- ΔH>0: Net heat loss by predominant endothermic reactions
- Thermodynamic equilibrium composition is matching the test data in the 650-700°C range
- 1.5 hrs to reach thermal steady state. Lonf transitory due to extensive thermal intertia of stainless steel reactor.

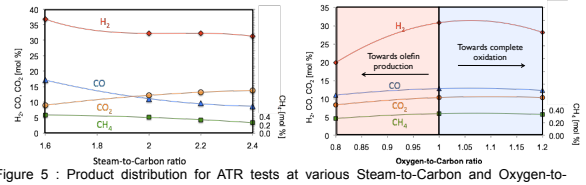


Figure 5 : Product distribution for ATR tests at various Steam-to-Carbon and Oxygen-to-Carbon ratios. Local maximum for Hydrogen generation at the syngas stoichiometry (O/C=1)

SUMMARY

•ATR Reactor product distribution matches thermodynamic equilibrium calculation
•Lightoff transitory was investigated, showing an unexpected CO2 generation
•Significant CO2 generation during light off exhibits a local maximum and is likely attributable to the Water Gas Shift reaction.

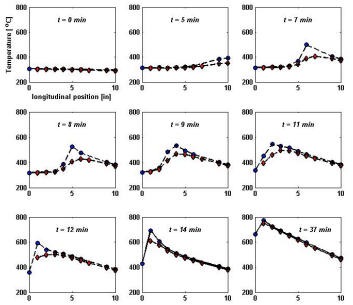


Figure 6 - Catalyst lightoff: The evolution of the ATR temperature profile of the lightoff front along the reactor axis. Fin and skin temperatures are superimposed. Difference between fin and skin temperaure are proportional to the heat flux out of the reactor. Lightoff occurs in the backend of the catalyst bed and propagates upstream to the front.

- O_2 consumption and CO_2 production begins before actual catalyst lightoff.
- Back-end catalyst lightoff is observed
- GC reading during reaction front propagation indicates full O_2 consumption and complete oxidation to CO_2.
- After upstreams propagation CO and H_2 are first detected
- CO_2 exhibits a local maximum concentration immediately after lightoff
- Skin temperature readings indicate adiabatic operation

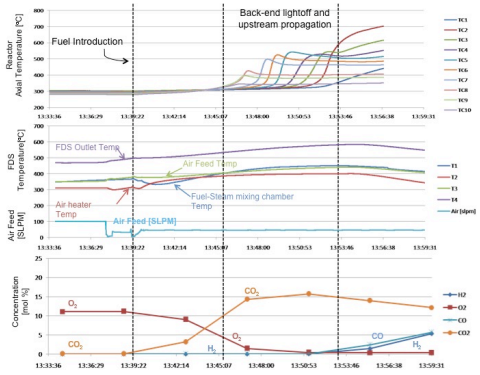


Figure 7 - Description of Lightoff test: *i)* Reactor temperature profile, *ii)* Fuel Delivery System temperatures, *iii)* Air feed flowrate, *iv)* Product distribution (H_2, O_2, CO, CO_2).

ACKNOWLEDGEMENTS

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