PAUL SCHERRER INSTITUT

Catalysis, Reaction Engineering and Systems Analysis to Produce Hydrogen From Liquid Energy Carriers by Partial Oxidation

E. Newson, F. Vogel, T.-B. Truong, K. Geissler, T. Schildhauer

Laboratory for Energy and Material Cycles, Paul Scherrer Institute
CH-5232 Villigen-PSI, Switzerland

Overview

For stationary and mobile fuel cell applications, the catalytic partial oxidation of methanol or hydrocarbons to hydrogen in a fuel reformer is studied. Experimental data from laboratory pilot plants (6 kW_{th}) with methanol feed, show that scaling up from microreactors leads to a loss of hydrogen yields and catalyst deactivation. Microreactor data with hydrocarbon refinery streams approach hydrogen yields with methanol. Systems analyses for well-to-wheel efficiencies provide targets for exceeding the efficiency of internal combustion engine systems.

Autothermal Steam Reforming and Partial Oxidation of **Methanol**[(2)]

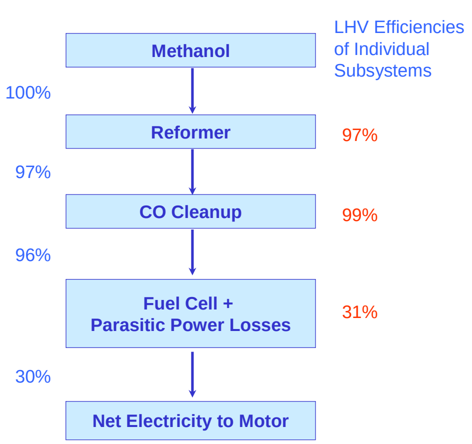
$4\ CH_3OH + 3\ H_2O + 0.5\ O_2 \rightarrow 4\ CO_2 + 11\ H_2$

Autothermal Steam Reforming and Partial Oxidation of **Isooctane**

$C_8H_{18} + 10\ H_2O + 3\ O_2 \rightarrow 8\ CO_2 + 19\ H_2$

(2) Gray, P. G.; Petch, M. I., Advances with HotSpot™ Fuel Processing, *Platinum Metals Rev.* **44**(3), pp. 108-111 (2000).

The Efficiency Cascade (PSI Systems Analysis)



Comparison of hydrocarbons and methanol as hydrogen energy carriers.

	Hydrocarbons	Methanol
Infrastructure	In place, conventional	Future, expensive
Properties	Flammable, water insoluble	Flammable and toxic, water soluble
Acceptance	Given	Questionable
H_2 potential (vol. basis)	1.96	1.0
Well-to-Wheel Efficiency [(1)]	27% (oil)	24% (natural gas)
Sustainable?	No	Yes

(1) Höhlein, B. L., IEA Advanced Fuel Cell Workshop, Wislikofen, Switzerland, p. 43 (1997).

Methanol autothermal reforming in a dual reactor pilot plant with commercial catalysts.

		Com. Cat. C (0.5-1.0 mm)	Com. Cat. B (1.0-2.0 mm)
Run time	h	57	50
MeOH conversion	%	50	64.5
H_2 production	kW_{th}	6.2	5.5
CO content	Vol%	0.39	0.56

Power Densities, kW_e per litre reactor volume (lrv)

- Methanol (250°C) ~ 27 kW_e/lrv
- Isooctane (500°C) ~ 16 kW_e/lrv

Well-To-Wheel Efficiencies (Lower Heating Value)

- Methanol (*ex* natural gas) Reforming Fuel Cell Car [(3)] 19 - 21%
- Gasoline Internal Combustion Engine Car 17 - 18%

(3) Methanol *ex* natural gas: 70% efficiency

Conclusions and Future Work

- Hot spot control in the pilot reactor limited the power density by reducing the hydrogen yield obtained in microreactors.
- Methanol reforming catalyst deactivation by sintering was observed after 60 hours of continuous operation.
- Hydrogen yields from hydrocarbons approaching yields from methanol.
- Increase the lower heating value (LHV) reformer efficiency for the hydrocarbons to 80%.
- Optimization of the fuel reformer subsystem to exceed the system efficiency target of 21%.

Acknowledgments

The project was supported by the Swiss Federal Office of Energy (BFE). Commercial catalysts were supplied by Johnson Matthey plc (UK) and Süd-Chemie (D) under confidentiality agreements. P. Binkert (PSI) was responsible for construction work.