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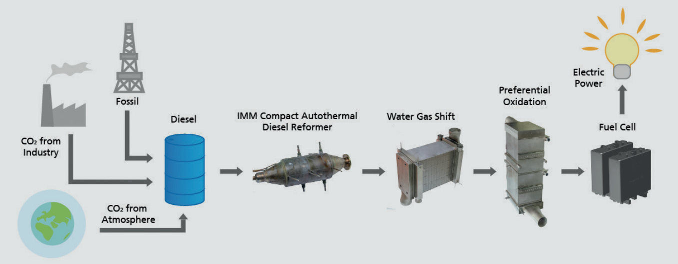

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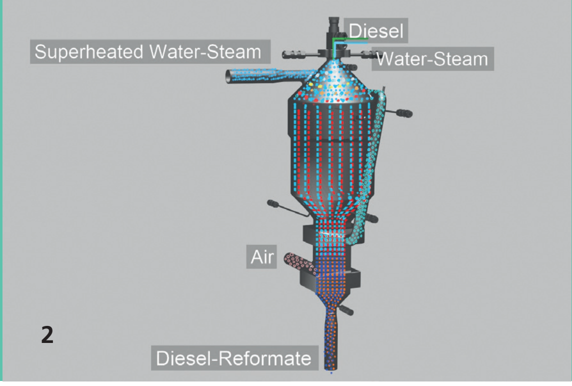

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1 *Utilization of diesel as hydrogen supply for fuel cells - sustainable and compact*
2 *IMM compact diesel autothermal reformer*

IMM COMPACT DIESEL REFORMER – HYDROGEN SUPPLY FOR MOBILITY

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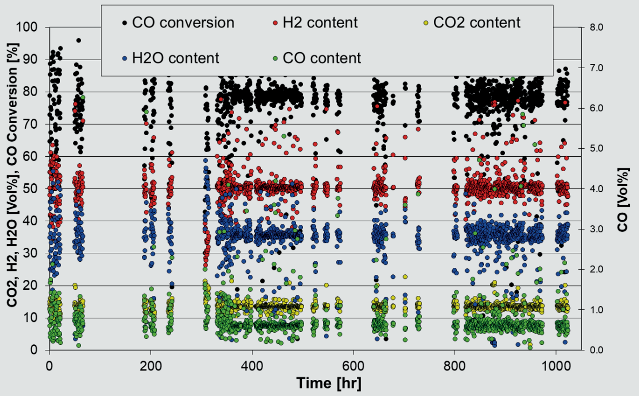
Mobile fuel cell applications require compact and simple hydrogen supply considering also the still limited availability of compressed hydrogen. For many portable and mobile applications, diesel is an attractive alternative to compressed hydrogen owing to its high availability, higher power density and easy transportation.

Fossil diesel can be processed now, synthetic diesel is available already nowadays (SHELL VPower), but diesel can also be produced from renewable sources in future, also from carbon dioxide from industrial processes such as cement fabrication or even from the atmosphere. The conversion of diesel to hydrogen (named reforming) is easier compared to gasoline, which requires higher temperature of the reforming process. The reformate is then fed to a fuel cell (possible are high and low temperature PEM fuel cells, but also Solid Oxide Fuel Cells) which produce electric power.

Catalytic autothermal diesel reforming

IMM has developed a highly compact autothermal diesel reformer and fuel processor components:

- Robust catalyst, no pre-treatment necessary, no performance drop after longer shut-down
- Catalyst coating similar to automotive exhaust cleaning reduces catalyst demand further
- Stable catalyst operation at partial load allows system modulation
- Reactor fabrication similar to automotive exhaust gas treating systems (core part are monoliths, several suppliers worldwide available)
- Catalyst technology is suited for fossil and synthetic diesel, this allows a seamless transition of fossil diesel based power generation towards future sustainability
- Compact water-gas shift reactor with integrated air cooling for CO clean-up (especially required for PEM fuel cells)



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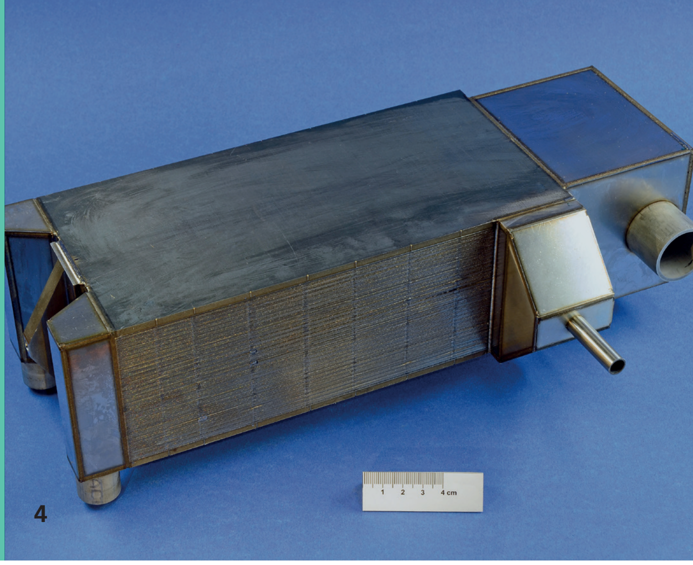

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- Compact preferential oxidation reactor with integrated evaporation cooling for CO fine-clean-up (especially required for low temperature PEM fuel cells)

IMM diesel autothermal reforming catalyst technology – tailor-made for the fuel

Benefit from 18 years' experience in reforming catalyst development for reforming, CO-clean-up and combustion.
Our excessive experience in diesel reforming and related catalyst development [1] proved that steam reforming is not suited for conversion of diesel fuels. Rather autothermal reforming has to be applied.

- Autothermal diesel reforming is operated in the temperature range between 750-800 °C thermally self-sustaining through addition of steam and air to the diesel feed.
- Therefore related catalysts are not sensitive to air exposure.
- Thermodynamic equilibrium dictates the generation of significant amounts of carbon monoxide in the reformer.
- IMM has self-developed, highly active and robust water-gas shift catalyst technology available for the first stage of carbon monoxide removal [2].
- IMM has self-developed, highly active and robust preferential oxidation catalyst technology available for the second stage of carbon monoxide removal (fine clean-up down to below 10 ppm carbon monoxide).

The stability and robustness of our catalyst technology has been proven in the lab by excessive long term testing (see figure) and in practical operation in reactors of up to 20 kW scale.

IMM compact autothermal diesel reformer reactor technology - tailormade for the reaction

Benefit from 20 years' experience in development or reformers for a large variety of fuels (also methanol, ethanol and many others).
Diesel autothermal reformer reactors are monolithic reactors, which have been developed for automotive applications. They have a number of advantages:

- They do not suffer from catalyst attrition - especially important for mobile applications.
- The catalyst applied as coating is fully accessible and consequently the required catalyst mass is minimized.
- The reaction is self-sustaining through air addition (partial oxidation generates heat which is partially consumed by steam reforming downstream in the reactor.

Substantial heat is contained in the fuel cell off-gas which can also not be utilized efficiently for steam generation in IMM compact evaporators (see figure).
All these issues are addressed by IMM compact reformer technology. The application of catalyst coatings in plate heat exchangers for water-gas shift and preferential oxidation allows optimum catalyst utilization and heat management through integrated cooling functions.
The robustness of this technology has been proven in practical applications under conditions of start-up, stationary operation and load changes [3].

3 *Long term stability test of IMM self-developed catalyst for water-gas shift*
4 *IMM compact hot gas driven evaporator*

Benefit from 18 years' experience in fuel processor development for stationary, mobile (aviation, maritime, ground transport) and portable applications. Apart from the reformer, the fuel cell hydrogen supply requires devices for evaporation, heat exchangers, a reactor for water-gas shift and in case of low temperature PEM fuel cell technology a reactor for CO removal and other balance-of-plant. The whole assembly is named fuel processor. IMM has developed compact and highly integrated high-performance components for that. The fuel processor design needs to be optimized for your specific application:

- the fuel cell type,
- the power range,
- the specific environment,
- the specific market requirements (achievable price and sales numbers) because fabrication techniques need to be chosen accordingly.

Talk to our experts to get the optimum solution for your system!

References

[1] O'Connell, M. et al. Development and evaluation of a microreactor for the reforming of diesel fuel in the kW range. Int. J. Hydrogen Energy 2009, 34, 6290.
[2] Kolb, G. et al. Water-gas shift reaction in micro-channels… Catal. Today 2005, 110 (1-2), 121.
[3] O'Connell, M.et al. An investigation into the transient behaviour of a microreactor system for the reforming of diesel fuel in the kW range. Chem. Eng. Technol. 2009, 32 (11), 1790.