FRAUNHOFER INSTITUTE FOR MICROENGINEERING AND MICROSYSTEMS IMM

1 IMM 50 kW single stage methanation reactor with integrated oil cooling

2 IMM pilot plant (10 kW power equivalent) for testing of the two-stage reactor concept

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POWER-TO-GAS – METHANATION OF CARBON DIOXIDE IN IMM COMPACT MICROSTRUCTURED REACTORS

Renewable energy sources require reliable and efficient storage systems to deal with the usually intermittent availability of these forms of energy (e.g. electricity from wind or photovoltaic facilities). Its storage through the conversion of carbon dioxide from biogas plants into methane is an option with numerous advantages:

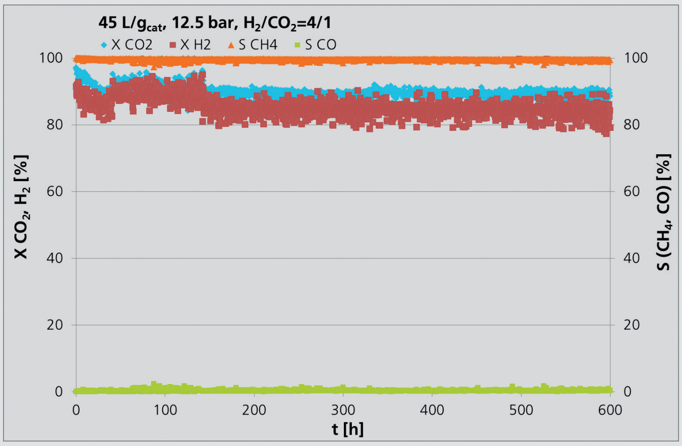
- High flexibility in end-use,
- long-term storage,
- clean-burning properties of this energy carrier.

Furthermore, methane production from renewable sources can take full advantage of the existing and well-established natural gas distribution infrastructure.
However, methanation still poses technical challenges that need to be adequately addressed:

- Required rapid response to dynamic operating conditions.
- Efficient heat management of the highly exothermic methanation reaction.
- Sulfur-resistant and highly selective catalysts are required to develop reliable and competitive processes.

Catalyst coated heat exchangers

While conventional methanation plants mostly rely on two-step fixed-bed reactor technology, Fraunhofer IMM has successfully applied its well established microstructured reactor approach to develop a novel process to face the new challenges in the transition towards a low carbon economy. Specifically conceived for carbon dioxide from biogas plants, a two-stage catalytic methanation process was developed. Thus, in a first step carbon dioxide is partially converted with the help of a monolithic reactor coated with high-temperature resistant catalysts.



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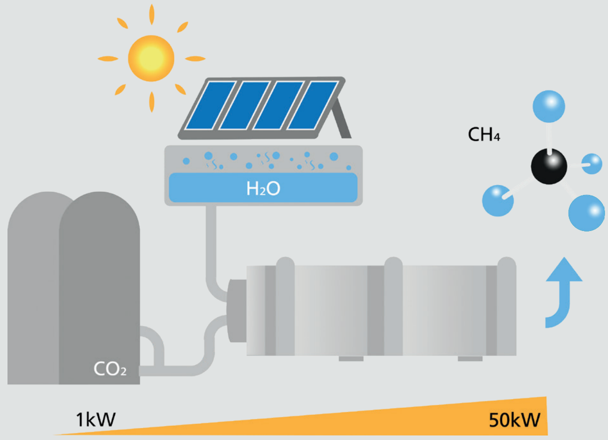

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Downstream, the remaining carbon dioxide undertakes reaction in an oil-cooled heat exchanger reactor operated at a much lower temperature. This configuration leads to a decreasing temperature profile and a high conversion rate, i.e. higher than 97 %.

IMM methanation catalyst technology – robust and tailor-made for dynamic operation

Benefit from 18 years' experience in catalyst development for gas phase reactions. At the core of this development is the employment of a new ruthenium-based catalyst. Long-term tests in lab scale demonstrated its high selectivity and stability, as well as strong resistance to the presence of traces of sulfur-based compounds, commonly found in raw biogas and possibly (temporary) present even after a biogas cleaning.

On top, a proprietary catalyst formulation could be developed for the first reactor stage which is resistant against the high reaction temperature, which was proven in excessive long-term testing. Testing under dynamic conditions and conditions of changing gas composition were performed to verify the practical applicability of our catalyst formulations. The outstanding characteristics of the new ruthenium-based catalyst as well as the stability of this two-stage process enable the production of regenerative methane that can be directly injected into the natural gas network. This adds a further degree of flexibility to this energy supply concept, making it suitable under a decentralized fuel production scenario that simultaneously takes advantage of the existing natural gas distribution infrastructure and local sources of carbon dioxide. The results generated in pilot scale are encouraging as the scaling-up is considered feasible to capacities in which carbon dioxide is available.

IMM compact methanation reactor technology – tailor-made for the reaction

Benefit from 20 years' experience in development of reactors for a large variety of reactions (fuel processing, combustion, fuel synthesis and many others).
Fixed bed methanation reactors have a number of disadvantages:

- The catalyst is not fully accessible and consequently the required catalyst mass is further increased.
- The first (monolithic) reactor stage is thermally self-sustaining and the reaction temperature limited by the thermodynamic equilibrium.
- The second reactor stage is a plate heat exchanger coated with catalyst and its temperature is controlled by oil cooling. A declining temperature profile is applied to follow the thermodynamic equilibrium and consequently maximise conversion.

All these issues are addressed by IMM compact methanation reactor technology [1] . The robustness of the plate heat exchanger reactor technology has been proven in practical applications under conditions of start-up, stationary operation and load changes for a variety of applications.

Reactor fabrication can be performed by cheap fabrication processes such as roll embossing of the plates, catalyst coating by screen printing and reactor sealing by laser welding. The monolithic reactor design relies in its core on automotive exhaust cleaning reactor technology.
In addition to ensuring a proper functioning of the catalysts and high conversion rates of carbon dioxide, the system for heat management allows the utilization of the energy released during methanation. The integration and subsequent use of this heat in district heating systems, for instance, make possible the even more efficient use of resources, and a direct reduction in the consumption of fossil fuels nowadays widely used for heating in almost all conventional district systems.
Furthermore, this type of technology is appropriate for the construction of modular plants that can be easily coupled to other carbon dioxide sources, hence facilitating their assembly, installation and subsequent operation.
Benefit from 18 years' experience in modular chemical plant development for a variety of applications!

References

[1] Neuberg, S. et al. CO2 methanation in microstructured reactors – catalyst development and process design. Chem. Eng. Technol. **2019**, 42 (10), 2076.

3 Long term stability tests of a methanation catalyst developed by Fraunhofer IMM

4 Coupling of a modular methanation plant to a biogas facility