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L-II | Experimental Validation of Methanol Synthesis from Steel Mill Gases

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Technological implementation of methanol synthesis from steel mill gases demands for in-depth understanding of both reaction kinetics and process behavior under fluctuating load conditions. Fraunhofer ISE operates a Methanol Miniplant at the Carbon2Chem® Technikum in Duisburg to provide experimental data for the validation, model adjustment and scale-up of the Carbon2Chem® technology with a high level of relevance for the industrial scale.

The Power-to-X Process Chain for Methanol

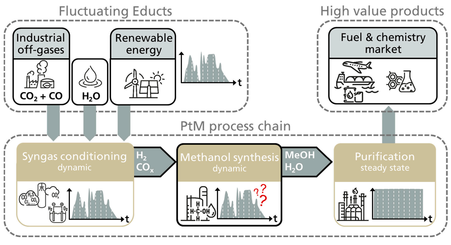

Fig. 1: Schematic illustration of PtX process chain via the dynamically operated methanol synthesis

- Dynamic operation of methanol synthesis process imposed by the upstream syngas source must be tackled by a robust process design and control layout
- Load flexible operation of methanol synthesis reactor is one important factor for an economic production of methanol produced from steel mill gases

Key indicators for reactor feed and output[1]:

Carbon Oxide Ratio $\quad COR = \frac{y_{CO_2}}{y_{CO}+y_{CO_2}}$

Stoichiometric Number $\quad SN = \frac{y_{H_2}-y_{CO_2}}{y_{CO}+y_{CO_2}}$

Weight Time Yield $\quad WTY = \frac{\dot{m}_{MeOH}}{m_{cat}}$

Experimental validation of the simulation platform

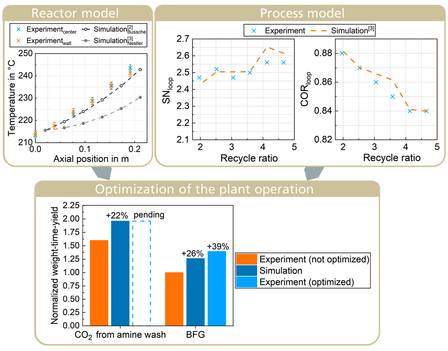

Fig. 3: Methodology for model validation and simulative plant optimization

- Measurements are reproduced by the model
- Optimized operating conditions based on simulations enable higher methanol productivity

Fraunhofer ISE Methanol Miniplant

Technical facts:

- Pressure: p ≤ 60 bar
- Temperature: 200 °C < T < 280 °C
- Flexible dosing of steel mill gases, H_2 and CO_2
- Industrial CLARIANT Catalyst, total mass 660 g, diluted with Al_2O_3
- MeOH/H_2O output up to 0.8 kg/h
- Currently 4,000 h time on stream

Process layout:

- Adiabatic two-stage quench bed reactor
- Recycle loop for unreacted syngas
- Total condensation of raw MeOH

Analysis concept:

- Highly resolved axial and radial temperature measurement in the reactors
- Online analysis of make-up gas, purge gas and liquid product

Fig. 2: ISE Methanol Miniplant in Duisburg

Reaction network:

$$CO_2 + 3H_2 \rightleftharpoons CH_3OH + H_2O \qquad \Delta H_R^0 = -50\ \mathrm{kJ\ mol^{-1}}$$
$$CO + 2H_2 \rightleftharpoons CH_3OH \qquad \Delta H_R^0 = -91\ \mathrm{kJ\ mol^{-1}}$$
$$CO + H_2O \rightleftharpoons CO_2 + H_2 \qquad \Delta H_R^0 = -41\ \mathrm{kJ\ mol^{-1}}$$

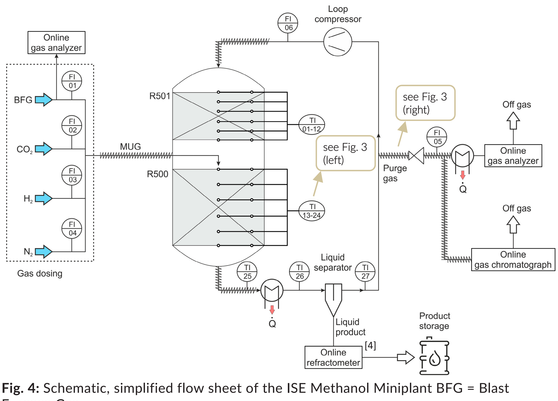

Fig. 4: Schematic, simplified flow sheet of the ISE Methanol Miniplant BFG = Blast Furnace Gas

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