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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 successfully completed operation of a Methanol Miniplant at the Carbon2Chem® technical center 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

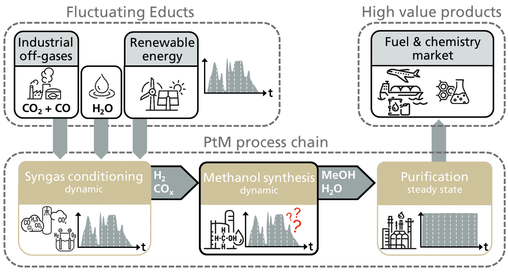

Fig. 1: Schematic illustration of PtX process chain via the dynamically operated methanol synthesis

Key indicators for reactor feed and output[1]:

Carbon Oxide Ratio	$\mathrm{COR} = \frac{y_{CO_2}}{y_{CO}+y_{CO_2}}$
Stoichiometric number	$\mathrm{SN} = \frac{y_{H_2}-y_{CO_2}}{y_{CO}+y_{CO_2}}$
Weight time yield	$\mathrm{WTY} = \frac{\dot{m}_{MeOH}}{m_{cat}}$

EXPERIMENTAL VALIDATION OF THE SIMULATION PLATFORM

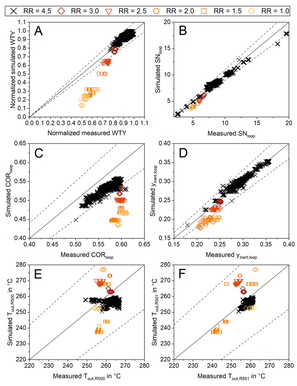

Fig. 3: Parity Plots for the model validation

- Measurements are reproduced by the model[2,3]
- Deviations at low recycle ratio only

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
- 6,300 h time on stream

Process layout:

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

Fig. 2: ISE Methanol Miniplant in Duisburg

Analysis concept:

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

Reaction network:

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

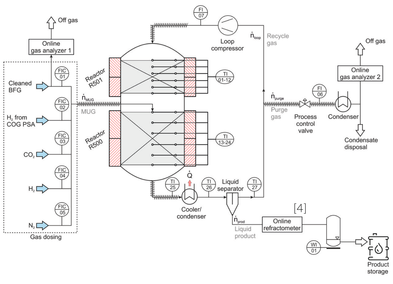

Fig. 4: Schematic, simplified flow sheet of the ISE Methanol Miniplant
BFG = Blast Furnace Gas

References
[1] Nestler, F. et al. (2018). In Chemie Ingenieur Technik. DOI: 10.1002/cite.201800026.
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[3] Nestler, F. et al. (2021). In React. Chem. Eng. DOI: 10.1039/D1RE00071C.
[4] Martens, M. et al. (2020). In Chemie Ingenieur Technik. DOI: 10.1002/cite.202000058.

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