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L-II | Initial Operation of the Demonstration Plant for Methanol Synthesis

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The demonstration plant for methanol synthesis was first operated from June 22nd to July 23rd 2021. The commercial catalyst was initially activated and then methanol was produced with constant conditions over two weeks followed by some variations of make-up gas composition to find out the operating limits of the plant. The experimentally determined methanol concentration of the liquid products agreed well with the calculated chemical equilibrium based on reactor exit temperature.

PLANT LAYOUT AND CONSTANT OPERATING CONDITIONS

The plant layout follows typical industrial design. The pressurized make-up gas is mixed with the recycle and this mixture is preheated and fed to the reactor. The reactor (single tube) has dimensions of tube bundle reators in commercial size (6 m length and 34.2 mm inner diameter) and is cooled by a boiling water jacket. The product gas is cooled down to condense methanol and water, which are separated from the unconverted gases. Originally the plant was designed for the conversion of pure CO_2/H_2-mixtures and was expanded for make-up gases with any adjustable ratio of CO/CO_2.

In the initial operation campaign the reactor was constantly operated with a boiling water temperature of 245 °C. Reactor pressure was controlled at 80 bar. Recycle ratio was kept constant at 5. Also, the stoichiometric number SN in the make-up gas was kept constant at 2.056. (SN=2.0 would be stoichiometric, so slight surplus of hydrogen was applied.)

$$SN = \frac{H_2 - CO_2}{CO + CO_2} \qquad COR = \frac{CO_2}{CO + CO_2}$$

MAKE-UP GAS COMPOSITION AND FIRST RESULTS

First the plant was operated in the original design point with a carbon oxide ratio COR of 1 for about two weeks. Afterwards CO_2 was partially replaced by CO with increasing share while reducing H_2 flowrate to keep the SN constant. In the end it was attempted to simulate Blast Furnace Gas (BFG) composition as carbon source with approximately 25 % CO_2, 25 % CO and 50 % N_2 (see table 1).
For all make-up gas compositions the reactor exit temperature stays the same, so the reactor reaches equilibrium in all cases. The more CO is in the make-up gas the higher the hot spot becomes. N_2 dilution also results in lower hot spot. The ripple in temperature profile towards the reactor end is an artefact and due to sensor aging.

Table 1: Makeup gas flow rates

Nr.	COR [-]	H_2 [Nm³/h]	CO_2 [Nm³/h]	CO [Nm³/h]	N_2 [Nm³/h]
1	1	3.82	1.25	-	-
2	0.9	3.79	1.15	0.13	-
3	0.7	3.72	0.94	0.40	-
4	0.5	3.64	0.71	0.71	-
5	0.3	3.56	0.45	1.06	-
6	0.1	3.46	0.16	1.45	-
7	0.5	3.64	0.71	0.71	0.71
8	0.5	3.37	0.66	0.66	1.31

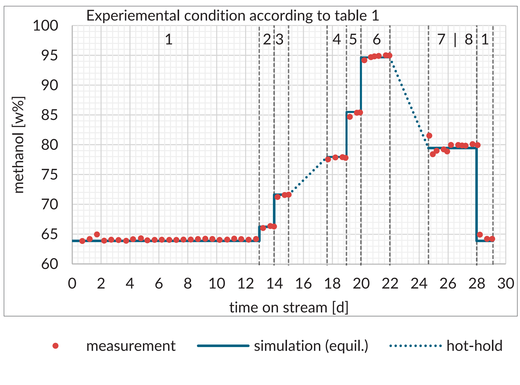

Figure 1: Liquid methanol concentration based on density measurement compared to chemical equilibrium calculated from reactor entry composition and exit temperature

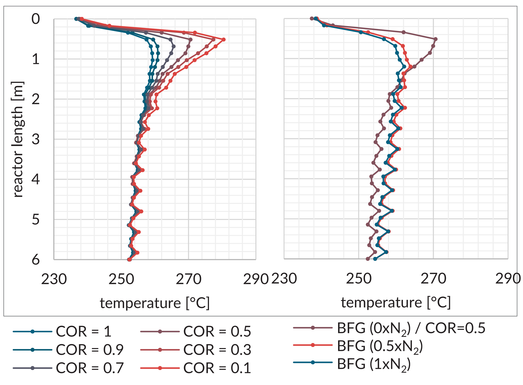

Figure 2: Temperature profile along reactor axis for variation of COR (left) and approach to operation with blast furnace gas by nitrogen addition (right)

A KEY BUILDING BLOCK FOR THE CLIMATE PROTECTION

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