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Methanol Synthesis with Steel-Mill-Gases: Simulation and Practical Performance Investigations

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Highlights

- Impact of different syngases from steel mills on MeOH productivity
- Catalyst stability at high CO_2 and H_2O concentrations
- Synthesis in close-to-practice test reactor system with intrinsic heat gradients
- Optimization of test conditions by sophisticated process simulation

1. Introduction

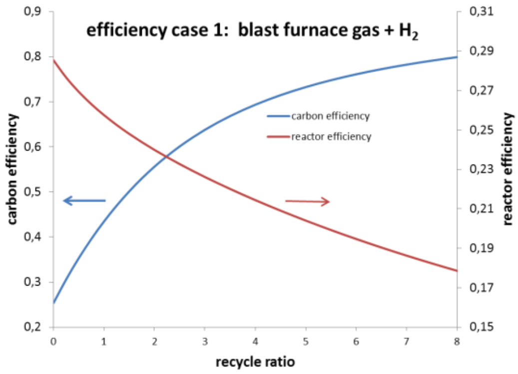
State-of-the-art steel mills as large and highly integrated sites comprise different sources of CO_2, CO and hydrogen. Besides the current energetic utilization, these gases provide promising potential to be utilized as feedstock for bulk chemical production, while simultaneously reducing the CO_2 footprint of the steel mill. The commercial Cu-based catalyst applied in industrial methanol synthesis is optimized for constant gas streams of high purity and fixed composition. The scope of this work is to evaluate the possibility of applying a commercial methanol synthesis catalyst in the conversion of synthesis gas derived from steel mill exhaust gases exhibiting fluctuating compositions [1]. The present contribution deals with the influence of altering CO/CO_2-ratios as well as the influence of high water concentrations in the inlet gas stream on the performance of the catalyst. In addition, gas streams with specific compositions from different steel mill production sites are investigated, including CO_2- and nitrogen rich blast furnace gases as well as gas streams originating from steel processing (converter gas). These gas streams have to be enriched with H_2 from electrolysis or coke oven gas. The ongoing investigations were performed within the scope of the project Carbon2Chem®, funded by the German Federal Ministry of Education and Research (BMBF).

2. Methods

Catalyst development and testing is usually performed with rather small amounts of catalyst [2]. However, transferring the results about performance and lifetime of the catalyst to industrial relevant pilot-scale application is hardly feasible. Here, larger amounts of differently shaped catalyst particles are usually applied resulting in a non-ideal temperature distribution and transport phenomena that can influence the overall performance of the catalyst. In order to close the gap between lab-scale and large-scale catalyst testing a new test system was developed [3]. In addition, a large scale methanol synthesis process simulation was developed including a kinetic model for the heterogeneously catalyzed methanol synthesis reaction. The theoretically identified operating points were subsequently applied in practice using two different test facilities. The first system is close to the industrially applied geometry. A second complementary test system with a total reactor volume of 15 ml is characterized by a higher grade of automatization.

3. Results and discussion

The ongoing research focuses on technically and economically feasible gas compositions and their impact on the overall catalyst performance. The carbon efficiency describes the total carbon utilization of the process and is shown in figure 1. The recycle ratio has to be kept in an economically reasonable range in order to enable high reactor efficiency. The CO_2/CO-ratio has a crucial effect on the catalyst performance.



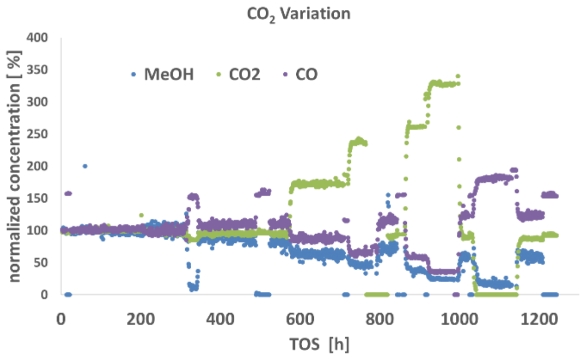


Figure 1: carbon and hydrogen process efficiency as a function of the recycle ratio (left)

Figure 2: MeOH formation depending on CO_2/CO (right)

As expected, the methanol productivity decreased with increasing CO_2 concentration (figure 2). A minimum CO_2 concentration is required for a high catalyst activity, as the lowest methanol productivity was obtained for pure CO. Apparently high water and CO_2-concentrations reduce the lifetime of the commercial MeOH-synthesis-catalyst.

4. Conclusions

The obtained results proof that methanol synthesis with H_2-enriched steel mill gases as feedstock is possible. However, for the same MeOH plant capacity a synthesis with steel mill gases requires a larger reactor due to lower catalyst productivity.

References

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