Study on the Impact of Various Biogas Compositions on Biomethanol Synthesis

Biomethanol Project

Student

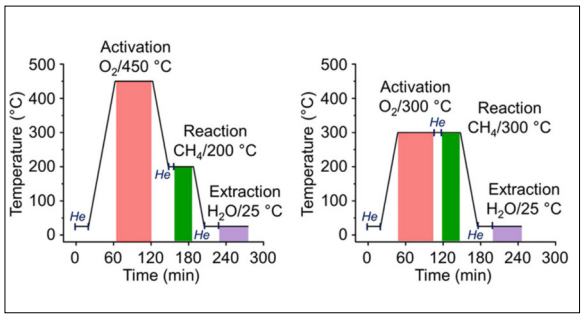
Nicolas Mutti

Initial Situation: Methanol is widely used across various industrial sectors, for both, as a chemical feedstock as well as a fuel precursor. However, only 0.2% of its global production currently comes from renewable processes. The predominant industrial method involves steam reforming of methane to produce syngas (CO and H2), followed by high-pressure hydrogenation. To reduce energy consumption, the Direct Methane to Methanol process is being investigated. The process converts methane directly into methanol using oxygen, thus avoiding syngas production. However, this process carries a high risk of explosion and requires additional purging steps. Recent studies suggest using biogas itself as an alternative oxidizing agent, which would eliminate explosion risks and help reduce atmospheric CO2 levels. At UMTEC (OST), a new catalyst has been developed that works with CO2 as the oxidizing agent, thus eliminating purging steps required in the conventional DMTM process. In Switzerland, biogas is purified using a three-stage membrane system that separates methane from CO2. Nevertheless, small amounts of methane remain in the waste gas, posing both environmental issues (due to methane's high global warming potential) and economic losses due to reduced process efficiency.

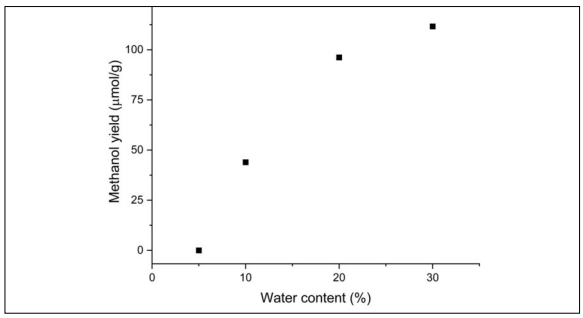
Objective: The objective of this work is, first of all, to identify the optimal gas composition to maximize methanol yield, using a mixture of CO2 and CH4 in each stage of the process (drying, calcination, activation, reaction and desorption) reaction and employing water in the final phase to desorb methanol from the copper-based catalyst. Subsequently, an experiment is conducted to evaluate the feasibility of methanol production in the presence of water during every step of the process. This will show if a condenser is required to separate water at the beginning of the process. Finally, three consecutive cycles were performed to analyze the performance of the copper-based catalyst in methanol synthesis.

Result: The results show that concentrations between 5 and 10 percent of CH4 are not sufficient to produce any methanol, as the high presence of CO2 inhibits the catalytic sites by forming carbon. The results obtained using water during each step of the process, also show that the presence of water prevents methanol production, probably due to blockage of the zeolite pores or immediate desorption of methanol. Finally, the stability of the catalyst over multiple cycles was analyzed, and here no methanol production beyond the second cycle was observed, possibly due to pore blockage by water or even methanol decomposition favored by the too long catalyst bed, in which methanol can be decomposed again.
Due to these unexpected results, countermeasures such as the use of a condenser is recommended to remove water before the reaction step, separating it from methane and carbon dioxide. Since low methane concentrations do not allow methanol synthesis, a mixture of 50% methane and 50% CO2 is therefore suggested to maximize yield. Finally, for further optimization, it is advisable to use a single gas composition for each process step, a strategy that allows a yield increase of 55.2%.

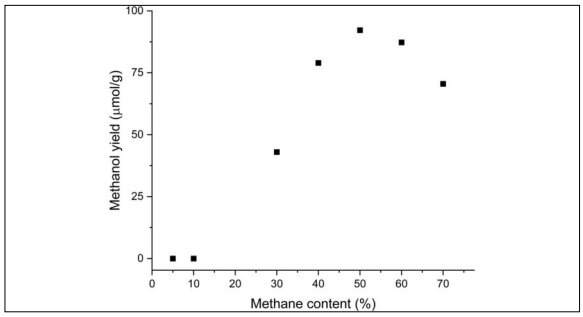
Conventional procedure (left) and the isothermal procedure (right) of the oxidation of methane to methanol.
https://dx.doi.org/10.1021/acs.chemmater.9b04223



Influence of different water content on the methanol yield.
Own presentment



Influence of different methane content on the methanol yield.
Own presentment



Advisor
Prof. Dr. Andre Heel

Subject Area
Energy and Environment