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Effects of a Changing Volume Flow on the Transient Methanation of CO_2 in a Wall-Cooled Fixed Bed Reactor

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Abstract

Considering the growing worlds energy consumption, the limitation of fossil energy and their high importance (market share approx. 69 % in 2014) it is necessary to develop new strategies to substitute the fossil energy sources. Furthermore, the burning of coal, natural gas and crude oil leads to an increase of atmospheric greenhouse gases, namely CO_2. Here, renewable energies such as wind and solar power, biomass as well as hydropower are highly viewed as alternatives for the future. However, renewable energies still lack on reliability for permanent demand; that is the high fluctuation of energy generated over time and the low storage capacity for surplus energy, in particular for wind and solar power.

For storing surplus energy the Power-to-gas concept is a promising technology; here hydrogen and carbon dioxide play the key role. By electrolysis of water using renewable energy, hydrogen is produced, but storage and transport of compressed or liquefied H_2 is expensive. Thus, chemical storage of hydrogen by forming methane is much more convenient; as carbon source CO_2 matches the idea of a renewable and sustainable cycle. This process is well-known as the Sabatier-reaction. Here, hydrogen reacts with carbon dioxide to CH_4 and water in an exothermic reaction (CO_2 (g) + 4 H_2 (g) $\boxtimes$ CH_4 (g) + 2 H_2O (g), ΔH^0_R= -165 kJ/mol). As source for CO_2, biogas with a carbon dioxide content of 25-55 vol.-% is attractive. Hereby, excess electricity can be stored, and biogas can be refined to synthetic natural gas (SNG). The evident advantage of natural gas and SNG are the already existing storage and transport infrastructure and the well-established C1 chemistry.

Since the Sabatier reaction is highly exothermic, temperature control is necessary to avoid thermal runaway and reach high conversion with the catalyst. Therefore, a model predicting the temperature profile in the reactor and the conversion satisfactorily is necessary.

Because access of surplus energy and, thereby, production of renewable hydrogen is subject to fluctuation, a transient operation of the reactor is needed to minimize the hydrogen storage capacity. One operational mode for transient operation is a changing volume flow. Here, the flow velocity of the gas in the reactor changes and hence the heat removal, residence time and partial pressures in the middle and the end of the reactor.

The effects of the changing volume flow will be presented and evaluated with regard to a transient mathematical model for the methanation of biogas with renewable hydrogen.