Investigation and optimization of the performance of a Methanation Reactor

There are several ways to store renewable energy in chemical bonds in the form of hydrocarbon fuels. One method is to convert CO₂ into methane via the Sabatier reaction.

\[ \text{CO}_2 + 4\text{H}_2 \rightarrow \text{CH}_4 + 2\text{H}_2\text{O} \]

The parameter used in this project in order to quantify the amount of methane produced is the CO₂ conversion into methane. The CO₂ conversion increases with pressure (Le Chatelier’s principle) but decreases when the gas flow increases (the number of molecules in the reactor is higher than the catalytic one). However, the Sabatier reaction exhibits an optimal temperature to achieve high CO₂ conversions since there is a competition between the kinetic (activation energy – red curve) and thermodynamic (exothermic reaction – blue curve) aspects. This is why the first step is to determine this optimum (280°C) through theoretical models.

Then, the different experiments are realized by varying the pressure, gas flow and temperature in the reactor and the CO₂ conversion is determined from a Fourier-transform infrared (FTIR) spectrometer.

Since the CO₂ conversion does not significantly increases after 5 bar, the pressure is kept constant during the experiments while the temperature and the gas flow (space velocity - SV) change. The highest CO₂ conversion (99%) is measured at 260°C at the lowest gas flow (0.14 s⁻¹). The CO₂ conversion (92%) allows us to produce 6 m³ of methane (1.2 kW) per day at the highest gas flow (0.55 s⁻¹), equivalent to heat 800 liters of water from 15 to 65°C.

A small-scale demonstrator is built at EPFL Valais-Wallis. It allows to store solar energy in the form of methane or methanol. This project is focused on the methanation process realized with a fixed bed reactor. The goals are to optimize the amount of methane produced by the reactor and to better understand the influence of pressure, temperature, gas flow and catalysts on the Sabatier reaction.

Although there are steps to improve (CO₂ sequestration, gas storage), this project shows us that methane can be produced from renewable energy and then used as fuel in order to meet the worldwide energetic demand.

Introduction and goals

Process

Results