A Multifunctional Reactor for Simultaneous Biomethane Purification and Production from Biogas

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Introduction

Biogas results from the degradation of organic waste and is a well-established process for the generation of renewable energy [1]. Biogas is mainly composed of CH_4 and CO_2, and it usually undergoes an upgrading process to remove the CO_2 and produce a near-pure CH_4 stream, the biomethane [1]. In the scope of Power-to-Methane processes, the CO_2 originated from the upgrade can be converted into more CH_4 (or synthetic natural gas) through the Sabatier reaction (Eq. 1), using H_2 produced from surplus renewable energy (via water electrolysis) [2].

$$CO_2 + 4H_2 \rightleftharpoons CH_4 + 2H_2O \qquad \Delta H_{298K} = -165\ kJ{\cdot}mol^{-1} \qquad (1)$$

Methods

In this work, the process of CO_2 removal (through sorption) and its catalytic conversion to more CH_4 were integrated in the same sorptive unit, in a cyclic and continuous multifunctional reactor. To this end, two sorptive reactors were filled with an hydrotalcite sorbent and a Ru-based methanation catalyst (both commercial materials). As illustrated in Fig. 1, the operation of the reactors consisted in their oscillation between two stages: sorption stage (the inlet was biogas) and reactive regeneration stage (the inlet was H_2). During the sorption stage (Fig.1, please refer to sorptive reactor A) the CO_2 was captured in the sorbent and the CH_4 exited as a purified stream. During the reactive regeneration stage (Fig.1, sorptive reactor B), the fed H_2 reacted with the previously captured CO_2, simultaneously regenerating the sorbent, and producing more methane. The inlets were switched periodically and so the sorptive reactors operated at 180 ° out of phase, until cyclic steady state was achieved. The performance of the cyclic sorptive-reactive unit was assessed through a parametric study to evaluate the influence of different operating conditions, namely, the inlet flow rate and CO_2 content during the sorption stage, the hydrogen inlet flow rate during the reactive regeneration stage, the stage duration, and temperature. The process was evaluated through several performance indicators namely CO_2 sorption capacity, CO_2 conversion, ratio of H_2 fed per CH_4 produced and CH_4 purity and productivity.

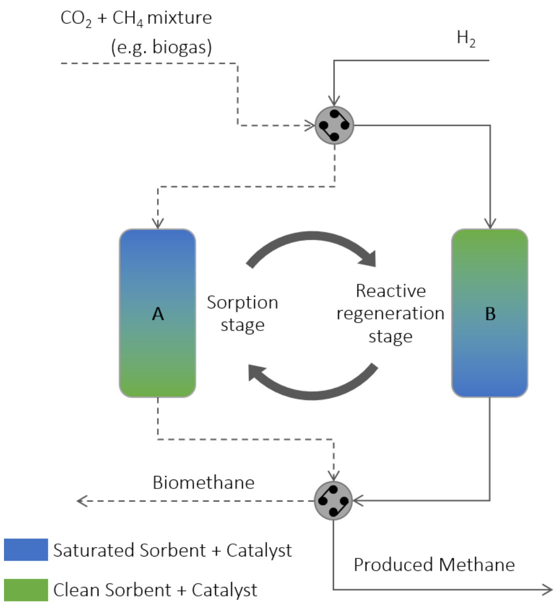

Fig. 1 – Scheme of the cyclic sorptive/reactive unit.

Conclusions

The cyclic sorptive/reactive concept was proven, and the parametric study allowed concluding that certain operating conditions can have a substantial effect on the performance of the cyclic unit and should be carefully considered for the optimization of the process. For instance, it was found that the rise of the H_2 inlet flow rate was beneficial to the regeneration of the sorbent (due to increased steam formation) and, up to a certain point it enhanced practically all process indicators, without severely compromising methane purity and/or causing CO formation.

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