Upscaling bubbling fluidized bed reactors for strongly exothermic methanation

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Highlights

- Pilot scale experiments conducted for CO2 methanation
- Wide range of operation conditions (37 kW to 200 kW)
- Concentration and temperature profiles measured
- Data allow upscaling and model validation

1. Introduction

Catalytic fluidized bed methanation has proven its ability to convert different sources of carbon oxides into methane rich gas streams, allowing for nearly isothermal conditions despite the strongly exothermic character of methanation. This has been shown during long duration tests both, for biogas methanation within PtX-applications [1] and for the conversion of gasification derived producer gas [2]. It could be demonstrated that the movement of the catalyst particles in the up-flow of reactive gas between zones with carbon depositing and less coking conditions enables a carbon management on the catalyst surface [2]. Due to this resilience of the fluidized bed reactor against coke formation, fluidized bed methanation was therefore chosen as second main production step for a planned demonstration plant in Tondela/ Portugal within the European Union project HyFuelUp. To broaden the technology basis with respect to part-load operation and to obtain performance data of the methanation reactor with the standard operation and state-of-the-art feedstock, the pilot-scale methanation plant at PSI (200 kW) was operated with gas composition according to CO_2 methanation.

2. Methods

The reactor diameter (22 cm) and the bed height (up to 2 m) of the pilot reactor (Figure 1) are chosen such that the results (up to 11 bar) can be considered representative for larger reactors. The plant is thus able to conduct experiments on the technical readiness level (TRL) 6. From top, an axially movable sampling tube is introduced allowing to measure temperatures and to take gas samples. Nearly continuous profiles of temperature and concentrations can be obtained for the lower half of the bed, while in the upper half of the bed, the device comprises additional four sampling points.

The different sampling points in the plant were connected by 16 stainless steel capillaries with micro gas chromatographs (mGC) as analytical device. In the analytical room, the flow of each individual sampling line can be controlled before the gas flows are distributed via a system of valves to the different mGCs. The micro gas chromatographs are regularly calibrated and can quantify the expectable species H_2, CO, CO_2, CH_4, and N_2, and also He, O_2, ethane, propane and certain sulphur species if present.

Figure 1 Reactor of the pilot plant for bubbling fluidized bed methanation

3. Results and discussion

A wide range of operation conditions could be tested starting from 37 kW methane output representing low part load (15-20%). 200 kW methane output was reached without issues; significantly more will be possible (only CO_2 supply is limiting right now due to a too narrow valve in the suppl system). The concentration profile of the 131 kW experiment as example in Figure 2 shows that significant reactor volume is needed to convert the hydrogen and to form methane. The reaction progress of this volume contracting reaction system can also be followed by the concentration of the nitrogen (leaking in from a non-tight valve). Taking out the N_2 concentration (assuming a situation with a tight valve), one can see that very high methane concentration close to 90% can be easily reached due to the low stoichiometric excess of hydrogen (H_2/CO_2 = 4.07). According to the recent changes in injection specification Switzerland, this gas would be close to fit the specification for unlimited injection without any further upgrading (besides drying). This is even more the case when instead of pure CO_2, biogas (60% methane, 40% CO_2 is converted). Then, more than 95% methane would be reached which is sufficient in many European countries for unlimited injection.

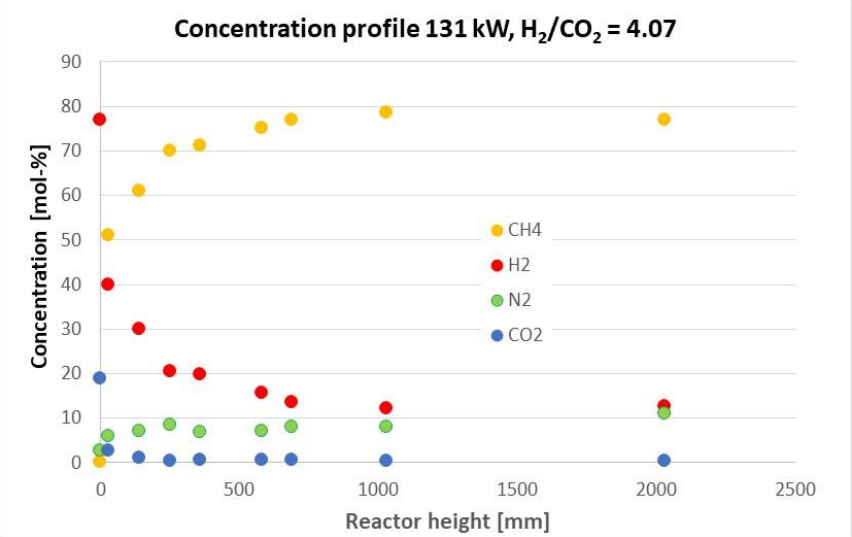

Figure 2. Concentration profile measured in PSI's pilot scale methanation reactor.

4. Conclusions

Performance data of the methanation reactor with the standard operation and state-of-the-art feedstock were obtained. For this, the pilot-scale methanation plant at PSI (200 kW) was operated with gas composition according to CO_2 methanation. The gas was taken from bottles in case of CO_2 and from a PEM-electrolyser in case of hydrogen. Proper sampling of the gas at several heights of the reactor as well as many thermocouples inside allowed obtaining axial temperature and concentration profiles. These data allow a detailed understanding of the reactor performance and validation of reactor models in ongoing work to support scale-up. A wide range of operation conditions could be tested. Further, it was possible to investigate flexibility of the system with respect to turn-down ratio, start-up & load change procedures.

References

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Keywords

Methanation; Bubbling fluidized bed; Pilot plant; Concentration profiles