An efficient and compact plate-type reactor for large-scale biogas methanation

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A biogas methanation reactor is designed to adapt the heat transfer over the axial coordinate, generating the optimal conditions for the reaction in agreement with the advancement of the conversion curve. Initially, large heat transfer is achieved thanks to the cooling through the large surface plates. The reactor is composed of thin plates, separated chambers where the catalyst is filled. In the plates, boiling water is circulated, so that large heat transfer can be achieved and the temperature of the cooling medium can be controlled with precision. After the unavoidable (but limited) hotspot, the temperature is controlled by keeping the boiling water at the target temperature of maximum reaction yield (approximately 230 °C). Thanks to the large exchange surface, the temperature is controlled precisely, achieving the maximum CO_2 conversion possible. The steam produced is collected in a steam drum on top of the reactor. Water is then circulated from the steam drum in a descending pipe that feeds back the water to the bottom of the reactor. The maximum steam content in the cooling plates is kept below 5%, to maintain the circulation via natural draft. In this way, a precise temperature control of the reactor is achieved without need of mechanical parts for the circulation of the cooling medium. The catalyst employed is based on Ni/ZrO_2.

The reactor was operated for several hundred hours in the biogas methanation. Thanks to the large heat exchange and the precise temperature control, the reactor produced grid-compliant synthetic natural gas (SNG) over more than 1000 hours of operation. This was accomplished without exceeding the maximum temperature allowed by the catalyst (ca. 580 °C). A characteristic temperature profile at the reactor activation is shown in figure 1. The heat transfer limited region in the reactor is limited to the hotspot, as visible in the change of slope in the temperature profile after approximately after 0.8 m of reactor. In this way, the predicted optimal reaction pathways (in terms of conversion vs. temperature) is approximated well, minimizing the reactor size. The reactor was targeting a GHSV of 1000 h^{-1}, but the experiments showed the possibility to higher the space velocity to 2000 h^{-1}. Additionally, it was possible to operate the reactor in partial load without problems and still producing grid compliant SNG. In this presentation, we will show several characteristic results of the reactor operation, demonstrating how this reactor type is particularly suitable for the CO_2 methanation reaction. Additionally, we will show how the reactor can be further scaled up, adding more plates, with the target of reaching a throughput of at least 400 Nm^3/h of SNG production.