Particle Circulation between Interconnected Slurry Bubble Columns for Sorption-Enhanced Fischer-Tropsch Synthesis

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Sorption-enhanced Fischer-Tropsch (SEFT) synthesis has gained recent attention for producing liquid hydrocarbons with higher conversions compared to conventional FT synthesis [1]. The FT reaction is an exothermic polymerization reaction where synthesis gas (CO and H_2) is converted on iron- or cobalt-based catalysts to a range of hydrocarbons and water. Using water-gas-shift active iron-based catalysts, CO_2 can be directly used as carbon source. Removing the produced water shifts the equilibrium towards the production of CO, which is then converted to long-chain hydrocarbons in the FT reaction [2]. Furthermore, several authors [2,3,4] reported oxide formation and structural changes at high water partial pressures during FT synthesis on cobalt catalysts. Besides the deactivation of the catalyst and the associated reduced catalyst lifetime, kinetic inhibition is a significant issue to consider about. Jacobs et al. [4] postulated that a temporary decline in conversion is due to the kinetic inhibition of water molecules, blocking the active sides of the catalyst. Thus, SE operation enhances the process with faster reaction rates, conversion enhancement and extended catalyst lifetime.

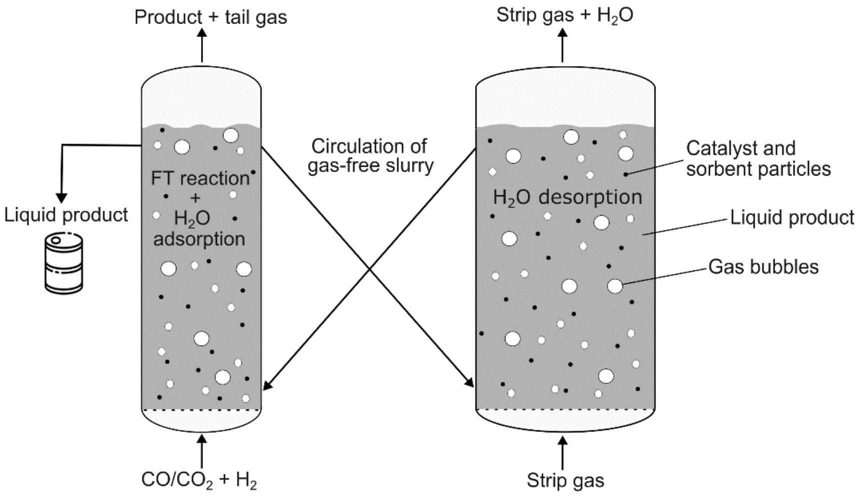

Figure 1: Interconnected slurry bubble columns for SEFT synthesis [5].

Asbahr et al. [5] proposed a new reactor concept (Figure 1) combining FT reaction and in-situ water adsorption in one slurry bubble column (SBC) and water desorption in a second SBC. The liquid circulation was successfully demonstrated in a cold flow model by Jafarian et al. [6], with main influencing parameters, i.e. gas holdup and reactor geometry, shown by Asbahr et al. [5]. In the same cold flow model, the volume and mass flow of the slurry between the two SBCs (circulation rate) were measured at ambient conditions using a Coriolis device (Optimass 7400C, Krohne). Initially, the volume circulation rate of water was compared between the Coriolis device and an ultrasonic flow sensor. Figure 2 shows that the measurements from the ultrasonic flow sensor (in blue) are consistently lower than those from the Coriolis device (in red), with a mean percentage error <4%. For the first time, a slurry circulation with 10 wt.% SiC (particle diameter: 53 - 75 µm) was achieved and measured only with the Coriolis device. Since gas holdup drives the circulation [5] and decreases with increasing mass fraction [7], the circulation rate of the slurry (10 wt.% SiC) is lower than the liquid circulation (0 wt.% SiC) for all superficial gas velocities. At u_G = 0,2 m s^{-1} a particle circulation of 393 g min^{-1} was reached, corresponding to nearly 10 wt.% in the loop. This shows the suitability of the new reactor concept for slurry circulation and demonstrates the potential for SEFT synthesis. Further studies need to investigate the effect of higher mass fractions, up to 35 wt.%, to assess the feasibility of operating commercially relevant SEFT synthesis in the new reactor concept.

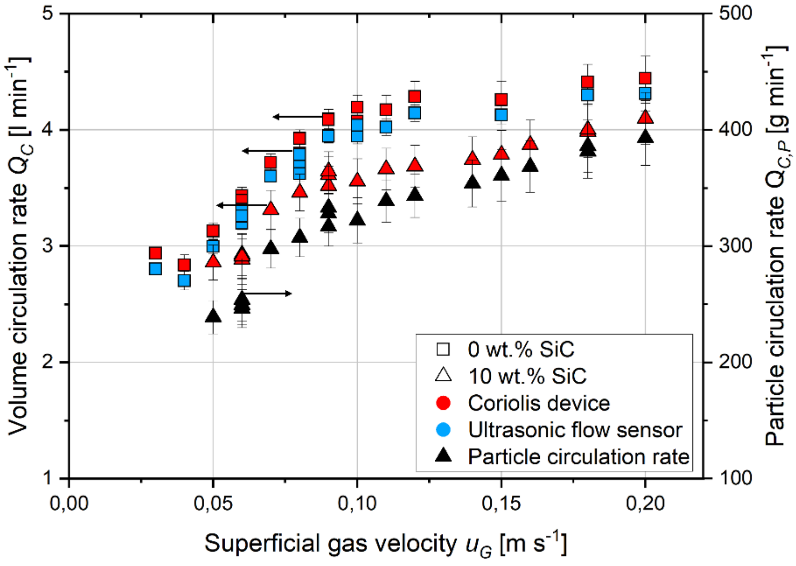

Figure 2: Volume (Particle) circulation rate QC(,P) for different superficial gas velocities uG and mass fractions of SiC (0 and 10 wt.%).

References

[1] Lj. Gavrilović, S. S. Kazi, A. Oliveira, O. L. I. Encinas, and E. A. Blekkan, ‘Sorption-enhanced Fischer-Tropsch synthesis – Effect of water removal’, *Catal. Today*, vol. 432, Apr. 2024, doi: 10.1016/j.cattod.2024.114614.

[2] M. P. Rohde, G. Schaub, S. Khajavi, J. C. Jansen, and F. Kapteijn, ‘Fischer–Tropsch synthesis with in situ H2O removal – Directions of membrane development’, *Microporous Mesoporous Mater.*, vol. 115, no. 1–2, pp. 123–136, Oct. 2008, doi: 10.1016/j.micromeso.2007.10.052.

[3] C. H. Bartholomew and R. J. Farrauto, *Fundamentals of Industrial Catalytic Processes*, 1st ed. Wiley, 2005. doi: 10.1002/9780471730071.

[4] G. Jacobs, T. K. Das, P. M. Patterson, J. Li, L. Sanchez, and B. H. Davis, ‘Fischer–Tropsch synthesis XAFS’, *Appl. Catal. Gen.*, vol. 247, no. 2, pp. 335–343, Jul. 2003, doi: 10.1016/S0926-860X(03)00107-8.

[5] W. Asbahr, R. Lamparter, and R. Rauch, ‘A Cold Flow Model of Interconnected Slurry Bubble Columns for Sorption-Enhanced Fischer–Tropsch Synthesis’, *ChemEngineering*, vol. 8, no. 3, p. 52, May 2024, doi: 10.3390/chemengineering8030052.

[6] M. Jafarian, Y. Chisti, and G. J. Nathan, ‘Gas-lift circulation of a liquid between two inter-connected bubble columns’, *Chem. Eng. Sci.*, vol. 218, Jun. 2020, doi: 10.1016/j.ces.2020.115574.

[7] S. Orvalho *et al.*, ‘Flow regimes in slurry bubble column: Effect of column height and particle concentration’, *Chem. Eng. J.*, vol. 351, pp. 799–815, Nov. 2018, doi: 10.1016/j.cej.2018.06.115.