**Process Integration for Decentralized Power to Fuel Conversion Based on Fischer-Tropsch Synthesis**

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**Highlights**

* Production of liquid fuels by coupling Fischer-Tropsch synthesis and hydrocracking.
* Integration of Fischer-Tropsch synthesis and hydrocracking in a single-stage microstructured reactor.
* Different integration patterns influence the performance of the coupled process.

**1. Introduction**

Global warming is to be limited to a maximum of 2 °C by 2050 compared with the pre-industrial level [1]. The transport sector's share of anthropogenic greenhouse gas emissions as a percentage of total emissions is almost 20 %, and global demand for mobility will even rise steadily in the future due to the growing world population and rising living standards. Studies show that liquid fuels will continue to play an important role in the transport sector in the future alongside alternative options such as e-mobility and hydrogen, especially for heavy goods vehicles and air traffic. So-called power-to-fuel technology can contribute to the transition of the transport sector from fossil fuels to CO2-neutral fuels. Renewable energy and carbon dioxide are converted into alternative liquid fuels. These fuels are characterized by negligible aromatics and high volumetric energy density and the drop-in quality makes it possible to use the existing infrastructure [2]. An attractive process route is via Fischer-Tropsch synthesis (FTS) and hydrocracking (HC). Decentralized, compact plants based on process intensification enable dynamic operation in order to meet the challenges of strongly fluctuating and locally distributed renewable energies.

Related to the Kopernikus project Power-to-X and funded by the Peter-und-Luise-Hager Foundation, the process integration of cobalt-catalyzed low temperature Fischer-Tropsch synthesis with the hydrocracking of FT products in one microreactor is investigated in this contribution.

**2. Methods**

A Co/Re-Al2O3 catalyst was selected for the FTS with 20 wt% cobalt and 0.5 wt% rhenium as promoter. It was prepared by an impregnation method with γ-Al2O3 (3 µm, 80-120 m²/g) as support and an aqueous solution of cobalt nitrate and perrhenic acid. The catalyst was tried overnight at 120 °C and then calcined at 400 °C for 2 h. [3]

A Pt-ZSM5 catalyst was chosen for the HC with 0.5 wt% platinum. It was prepared by impregnating H‑ZSM5 with an aqueous solution of tetraamineplatinum(II)hydroxide. The catalyst was dried overnight at 120 °C and then calcined at 550 °C for 6 h. [3] Before testing, both catalysts were pelletized, crushed and sieved to obtain a size fraction of 50-100 µm. Moreover, both catalysts were characterized by common methods.

For the study of the single-stage integration of FTS and HC a micro annular fixed-bed reactor was designed (see figure 1). Both catalysts were reduced online in hydrogen atmosphere at ambient pressure and 350 °C for 15 h. Reaction conditions were: 30 bar, 225-260 °C, WHSV 6-12 h-1 and H2/CO ratio 1.9. All products leaving the reactor system were first separated in a wax fraction, liquid product fraction and residual gas by a hot trap (190 °C) and a cold trap (6 °C). The residual gas was directly analyzed by an online GC, whereas the liquid and the wax fractions were sampled and analyzed by an offline GC.



**Figure 1.** Micro annular fixed-bed reactor for the integration of FTS and HC.

**3. Results and discussion**

The integration of Fischer-Tropsch synthesis and hydrocracking in a single-stage microstructured reactor for the production of liquid fuels is feasible. The liquid fuel selectivity of the coupled process is higher than for the FTS at the same conditions, indicating that the long-chain hydrocarbons are selectively cracked. Quantitative statements, however, can only be made after the product analyses have been evaluated, but this has not yet been completed. As expected, the conversion increases with rising temperature and decreasing WHSV. Both catalysts showed a reasonable long-term stability during up to 120 h of experiments.

Two different integration patterns were investigated – the sequential bed and the hybrid bed. As anticipated, the catalytic performance of the coupled process is influenced by the integration pattern. As a liquid phase is involved in the process, dilution or bed configuration might effect the wetting of the catalyst particles as well as the flow through the catalyst bed [4]. The observed trends and the reproducibility needs to be further investigated to validate the importance of several possible parameters observed in the present study.

**4. Conclusions**

The integration of FTS and HC was investigated in a single-stage micro annular reactor for the production of liquid fuels. The coupling of FTS and HC increases the liquid fuel selectivity by selectively cracking the long-chain hydrocarbons. The integration pattern has an influence on the catalytic performance of the combined process. The experiments show that the operation of compact small-scale power-to-liquid plants seems possible.

**References**

[1] Paris Agreement, United Nations, 2015.

[2] Positionspapier „Fortschrittliche alternative flüssige Brenn- und Kraftstoffe: Für Klimaschutz im globalen Rohstoffwandel“, DECHEMA e.V., 2017.

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[4] G. Hong, Y. Noh, J. Park, etal., Catalysis Today 303 (2018) pp. 136-142.