CTL/GTL Technology based on Medium Temperature Fischer-Tropsch synthesis (MTFT): Fundamentals and Applications

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The catalytic Fischer-Tropsch synthesis (FTS), aiming at converting synthesis gas originated from coal, natural gas or biomass into liquid fuels and chemicals, has a long story with crude oil price fluctuations in the world. This reaction is typically catalyzed by either cobalt or iron based catalysts at 190 - 360 ℃ and 15 - 50 bars, leading to low temperature (190 - 240 ℃, cobalt and iron as catalysts), medium temperature (260 - 300 ℃, iron as catalysts), and high temperature (320 - 360 ℃, iron as catalysts) FTS processes named as LTFT, MTFT and HTFT processes, respectively. It involves the C1 monomer formation as initial step followed by a complicated reaction network for the formation of a series of hydrocarbons (linear paraffins and olefins) and oxygenates, mainly alcohols. The difficulties in reaction mechanism understanding, product selectivity control, high efficient and stable catalyst development, reactor technology and process integration make the large-scale FTS industrialization for target products production to be a great challenge.

Currently, LTFT has mainly been applied with cobalt catalyst by Shell and SASOL in gas to liquids projects, and HTFT with iron catalysts by SASOL for coal to liquids projects. Synfuels China Co. Ltd., a company evolved from the Institute of Coal Chemistry of the Chinese Academy of Science, has carried out systematic proprietary catalyst development, reactor scale-up, and process integration since 1997, and developed MTFT with iron catalysts in Coal to liquids projects. Notably, the High Temperature Slurry FT Process (HTSFTP) originates from this research. The catalyst used in this latter process is a proprietary high-temperature iron catalyst (named as SynFT-I) which was recently tailored for the high-temperature slurry-bed reactor. Compared to the conventional low-temperature slurry-bed process, the operating temperature of Synfuels China's HTSFTP is increased to approximately 275 ℃ by using SynFT-I. The major advantages of the HTSFTP over conventional low-temperature slurry-bed processes include: (1) a lower (about one-fourth) solid catalyst charge due to the ultra-active F-T synthesis catalyst being used; (2) the efficient recovery of FTS reaction heat from the slurry-bed reactor as steam up to 30 bar; (3) the production of high-quality FTS syncrudes with very low oxygenates, especially acids (about one-third); (4) an easy retrofit to both CTL and GTL processes. The results have proved to be very positive for the new FTS technology developed at Synfuels China. The iron catalyst reached a record hydrocarbon productivity of 0.8 - 1.2 g $gcat^{-1}$ h^{-1}, with a very low methane selectivity of less than 3 wt%. The productivity is even up to 1.5 - 2.5 g $gcat^{-1}$ h^{-1} for the new generation of iron catalyst. The slurry reactor operation demonstrated a very uniform distribution of temperature in the slurry bed, and separation of the catalyst from the wax proved to be highly efficient, such that the final diesel product was achieved. Synfuels China has formed a strategic alliance with several energy companies, with total capacities of 7 million tons per year until now.

This presentation will give a general review of the key issues of the process development, including systematic studies on the reaction mechanism, kinetic modeling and reactor simulation, specifics of high efficient iron catalyst and its manufacturing scale-up, reactor selection and reactor scale-up, process demonstration, and details of the industrialization.