Conversion of natural gas-(coal- or biomass-) derived synthesis gas to transportation fuels and chemical feedstocks via Fischer-Tropsch synthesis

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The renewed interest in conversion of syngas into hydrocarbons using Fischer-Tropsch synthesis (FTS) is principally due to the concerns about rational use of fossil and renewable resources. Both fossil and renewable resources can be converted into liquid fuels and chemical feedstocks using XTL (X-To-Liquid) technologies, where X can be natural, associated or shale Gas, Coal or Biomass. The heart of the GTL, BTL and CTL processes is the FTS reaction in which syngas is converted to hydrocarbons over a cobalt or an iron catalyst. Cobalt is the catalyst of choice for low temperature FTS and high H_2/CO feed ratio (GTL application), due to its high activity and selectivity towards desired products, as well as the absence of water-gas shift reaction. Iron based catalysts are used to process coal derived synthesis gas (low H_2/CO feed ratio), due to their ability to generate H_2 internally via the WGS reaction.

There are two general types of FTS technology that are currently employed on a commercial scale: high and low temperature Fischer-Tropsch (HTFT and LTFT), where the latter is typically used in the industry for synthesis of liquid fuels. LTFT is characterized by three-phase operation and is mainly conducted in two types of commercial reactors: slurry bubble column (SBCR) and multi-tubular fixed-bed reactors (MTFBR).

The reaction is highly exothermic and heat removal presents one of the main challenges when choosing the reactor type. However, other issues that also have to be considered are catalyst effectiveness, catalyst deactivation and regeneration, pressure drop etc. The major downsides of SBCR are difficult scale-up, separation of active catalysts from wax and catalyst deactivation due to attrition, while the drawbacks of MTFBR are high capital cost, poor heat removal, high mass transfer resistances and high pressure drop. Also, several micro-channel based Fischer-Tropsch reactors for small scale applications have been under development (Compact GTL, Velocys) and are ready for commercialization. Process intensification also improves attractiveness of FTS for conversion of ligninocellulosic biomass into synthetic fuels using BTL technology. The efficiency of the BTL process is strongly affected by the cost related to biomass collection and transport. Design of smaller highly efficient BTL units is expected to significantly improve the cost-efficiency.

Recent developments and trends in XTL technology, including a brief review of kinetic modeling approaches for primary and secondary reactions will be discussed in this lecture.