Recent Advances in the Development of Fischer-Tropsch Catalysts at Sasol

Tracy C. Bromfield, Anton C. Vosloo*

Sasol Technology R&D, PO Box 1, Sasolburg, 1947, South Africa
Email: tracy.bromfield@sasol.com

SUMMARY: Sasol's experience of more than 50 years in the field of Fischer-Tropsch puts it in a unique position to exploit the renewed interest in the utilization of the Fischer-Tropsch process to convert natural gas to liquids. In order to capitalize on this position, Sasol has made significant improvements to its low temperature and high temperature Fischer-Tropsch catalysts. A review is given of the development of Sasol's Co-based catalyst for low temperature Fischer-Tropsch applications. Sasol has also developed a new Fe-based catalyst for the high temperature Fischer-Tropsch process. The advantages of this catalyst compared to the existing catalyst are discussed.

Sustainable Development

In an era of fierce global competitiveness, Sasol as a technology company is acutely aware of the pivotal influence of sustainable development in determining success or failure. Pieter Cox, Sasol CEO, recently highlighted the profitable integration of continued technological progress and a more efficient use of ecological resources as being among the main business driver behind sustainable development.[1]

The Role of Fischer-Tropsch Synthesis

The Fischer-Tropsch synthesis lies at the heart of Sasol's array of technologies. Synthesis gas ($CO+H_2$) is converted via a step-wise polymerisation process to a myriad of products ranging from methane to long-chain hydrocarbons. Commercially, Sasol produces chemicals, fuels and monomers using iron-based catalysts in their Sasolburg and Secunda facilities.

Historically, Sasol's Fischer-Tropsch plants made use of fixed bed and circulating fluidised bed (Synthol) reactors for the production of wax and fuels. In the 1990's substantial advancement took place with the successful commercial implementation of the slurry bubble column and fixed fluidised bed (Sasol Advanced Synthol) reactors operated with iron-based

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catalysts (Figure 1). It is through these technological advances that Sasol is in a unique position to stake a claim as a leading petrochemical producer.

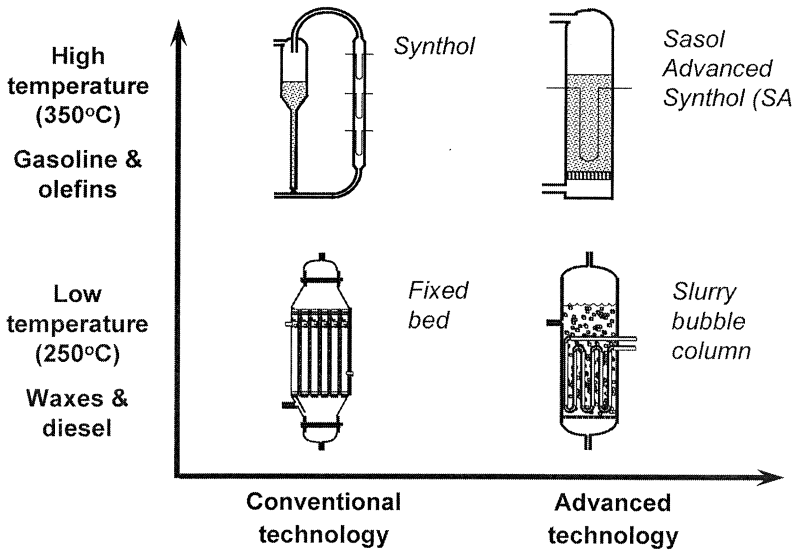

Figure 1. Advancement of Sasol's Fischer-Tropsch reactor technology

Besides being an established supplier of co-monomers such as ethylene and propylene, Sasol has a significant share in the hexene- and octene-market and further expansion in octene capacity is envisaged in the medium term (Figure 2).

While the commercial significance of even-numbered alpha olefins remains unquestioned, the emergence of new technology is expected to increase the demand for odd-numbered alpha olefins in the future. By virtue of its Fischer-Tropsch technology (which produces both odd and even numbered olefins) Sasol is ideally positioned to take advantage of this opportunity.

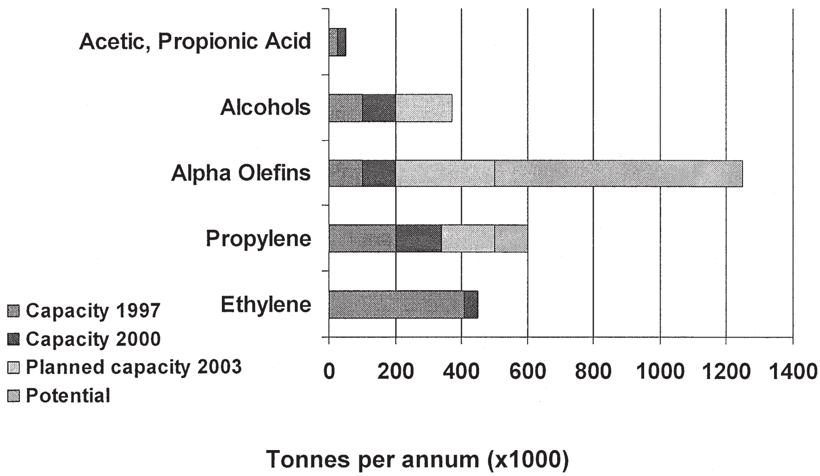

Figure 2. Petrochemicals recovery from Synfuel plants at Sasol from 1997

Gas-To-Liquids (GTL)

The advent of GTL (Gas to Liquids) technology as a means to monetize remote and stranded gas fields (or crude oil associated gas currently being flared or reinjected) in order to generate clean fuels and speciality chemicals, presents another opportunity for Sasol to leverage its Fischer-Tropsch technology. Broadly speaking, the GTL Fischer-Tropsch process yields 80% gas-oil and 20% naphtha that can be cracked to yield C_2 and C_3 olefins.

Sasol Chevron, a global joint venture with Chevron, was established in 2000 with the intention of globally manufacturing and marketing premium-grade alternative fuels produced via commercial application of GTL technology. At present, Sasol Chevron is establishing a GTL facility in the Escravos Delta of Nigeria. Concurrently, together with QGPC (Qatar General Petroleum Corporation), Sasol is also committed to another GTL venture in the Qatari port town of Ras Laffan. Both facilities are due for commissioning in 2005, and collectively will have daily production capacities in excess of 60 000 barrels (bbl).

Because of the considerable capital investment required, a cheap source of gas and a high per pass conversion are prerequisites for GTL to be economically viable. Under conditions of high syngas conversion, cobalt is preferred over iron as a Fischer-Tropsch catalyst because the kinetics of Fischer-Tropsch synthesis over cobalt-based catalysts are not limited by high partial pressures of water as is the case for iron-based catalysts. Moreover, cobalt exhibits negligible water-gas-shift activity and is most suitable for use with a feedstock having an H_2/CO ratio of 2, ideal from a stoichiometric viewpoint.

From Sasol's perspective, the choice combination for GTL would invoke a slurry bubble column reactor with a highly active and stable cobalt-based catalyst. Advantages of the slurry bubble column reactor include isothermal operation, ability to handle high gas throughput, and significant scope for scale-up. Sasol has vast experience in slurry bed reactors through the successful scale-up and commercialisation of its iron-based SPD (Slurry Phase Distillate) process at Sasolburg. This commercial experience goes a long way to address the technological risk associated with commericalising GTL technology, therefore much emphasis is placed on the development of a suitable cobalt-based catalyst.

The Sasol proprietary cobalt-based catalyst is carried on a modified pre-shaped support material which affords the necessary mechanical properties for successful slurry bed operation, as well as control over the product selectivity. The catalyst is prepared via aqueous slurry phase impregnation with a soluble cobalt metal source. The impregnation, drying and activation procedures have been optimised in order to achieve a homogeneous promoter distribution and increased online stability. Extended catalyst lifetime is imperative in ensuring the economic success of this catalyst at the commercial scale.

Sasol has successfully demonstrated the suitability of a first-generation cobalt-based catalyst for slurry bed application, and substantial improvements in the catalyst activity and selectivity are already being realised through second and third generation catalysts.

The manufacture of this proprietary cobalt-based catalyst is performed by Engelhard at the dedicated catalyst preparation facility situated in De Meern, The Netherlands. This facility will be used to supply catalyst for the GTL plants in Nigeria and Qatar.

High-Temperature Fischer-Tropsch

Since the 1950's, Sasol has been commercially producing fuels and chemicals using a two-phase application of the Fischer-Tropsch synthesis over iron-based catalysts. This process, conveniently termed High-Temperature Fischer-Tropsch, was initially performed in circulating fluidised bed reactors (CFB) using fused iron catalysts. The choice of catalyst was largely based on the mechanical integrity required to survive the abrasive environment inside the circulating reactor bed. Fused iron catalysts were inexpensive to produce and were found to possess sufficient attrition resistance to render them suitable for the CFB reactors. They are prepared via the addition of alkali and other promoters to a melt of magnetite at temperatures in excess of 1400 °C. This molten mixture is cast into ingots and cooled, whereafter it is crushed and milled to the required particle size. Unfortunately, as a result of the high temperatures required for fusion, solid-state reactions take place between the components present in the catalyst.

Furthermore, phase segregation occurs upon cooling, and promoters become trapped in occlusions, and are thus not homogeneously distributed throughout the catalyst particle. These factors contribute to fused catalysts being limited in the degree of flexibility available in the type and quantity of chemical promoters that can be added. This in turn results in limited scope for altering the product spectrum obtainable in the High-Temperature Fischer-Tropsch process. Notwithstanding this, fused catalysts have been the mainstay of Sasol's two-phase Fischer-Tropsch process for over half a century.

The advent of the SAS (Sasol Advanced Synthol) reactors in 1990, presented an opportunity for Sasol to expand its fuels and co-monomer business. In contrast to the circulating fluidised bed reactors of the past, these fixed fluidised bed reactors offer a far milder attrition environment for the catalyst. This presents an opportunity for change. Therefore, Sasol is developing a proprietary iron-based catalyst that will have sufficient mechanical integrity to withstand the abrasion inside the SAS reactors, but without the disadvantages inherent in the fused catalyst.

Development of such a catalyst is aimed at affording control over the catalyst morphology and chemical composition, as well as the interaction between the various chemical components. It is envisaged that this catalyst will allow for a more flexible product spectrum with fewer undesirable side-products. Additional benefits would include improved reactor operation and reduced catalyst consumption.

Conclusion

The recent advances in catalyst development for both the GTL and High-Temperature Fischer-Tropsch technologies at Sasol are significant in terms of the drive towards sustainable development. By leveraging its expertise in these areas, Sasol is ideally placed to globalise its Fischer-Tropsch technology and become a leader in the petrochemical industry well into the foreseeable future.

1. Sasol Safety, Health and Environment Report 2000, page 11