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Development of Integrated High Temperature and Low Temperature Fischer-Tropsch System for High Value Chemicals Coproduction

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Abstract

The conventional indirect coal-to-liquids process for transportation fuel production suffers from inefficiency in syncrude utilization and poor economic performance. This is largely because the FT syncrude are not properly used. In consideration of the potential synergies in fuel quality improvement and chemicals coproduction, for further high value utilization of the hydrocarbon products, the novel HTFT-LTFT system integrated high temperature Fischer-Tropsch process and low temperature Fischer-Tropsch process together is proposed based on the advanced coal gasification and FT techniques and modelled in Aspen Plus. Energy, exergy analysis and a detailed economic analysis are performed. The synergies of the integrated system is also discussed by comparing with the separated HTFT/LTFT system. Results show that the integrated HTFT-LTFT systems can increase the annual income by more than 10% by high utilization of FT syncrude and reduce the capital investment by 18.2% by sharing infrastructure. Higher energy and exergy efficiencies as well as internal rate of return (IRR) are achieved by the integrated systems. The integrated HTFT-LTFT system is more efficiently and economically than the separated HTFT/LTFT system. Therein the integrated HTFT-LTFT system coproduce both olefins and base oils simultaneously presents an excellent economic performance with IRR of 18%, much higher than the 4.7% of the separated HTFT/LTFT system.

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Keywords: Fischer -Tropsch, economic analysis, Aspen Plus, HTFT-LTFT system;

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1. Introduction

Fischer-Tropsch (FT) synthesis converts syngas to hydrocarbons and has a great importance for countries with the limited reserve of oil to meet the increasing energy demand. Indirect coal-to-liquids (CTL) process via FT in China has attracted increasing attention because of the oil and gas reserve. Significant progress FT technical development has been made recently, and the successful commercialization of the indirect CTL plant with the capacity of millions ton/year is a key technical breakthrough [1]. The current focus on the CTL process deals with the production of liquid transportation fuels (C5-C20) such as gasoline and diesel. Due to the lack of selectivity of FT towards gasoline and diesel, the capital intensive CTL process faces the poor economic performance. In addition to catalyst improvement and process condition optimization, the conventional effort to increase the selectivity of transportation fuel necessitates further extensive refining to convert lighter and higher hydrocarbons to transportation fuel range. However, the poor economic performance is because the FT syncrude are not properly used. FT syncrude can be further refined not only to transportation fuels, but also to high value chemicals[2].The lack of selectivity of FT towards gasoline and diesel provides an opportunity for the manufacture of chemicals. High value hydrocarbons production represents a valuable solution to increase the economic profitability on the industrial scale.

Integrated high temperature and low temperature Fischer-Tropsch (HTFT-LTFT) system represents a competitive advantage to conventional system with the production of high value products, and has the potential to a high average product price and a high yield of total hydrocarbon products[3]. The integrated HTFT-LTFT plant (Sasol I) was firstly developed in history in Sasolburg, South Africa. This HTFT-LTFT plant integrated American Kellogg circulating fluidized-bed Fe-HTFT and Arbeits-Gemeinschaft Lurgi and Ruhrchemie (ARGE, LTFT) fixed-bed Fe-LTFT processes. This plant shared the syngas production, the C3-C4 oligomerization and the aqueous component extract unit. However, the abovementioned HTFT-LTFT integrated plant suffers from three major problems: (i) The FT syncrude is only used for low value product production, such as gasoline, diesel and wax. The advantage of higher olefin content characteristic in the both Fe based FT products and higher wax yield in LTFT for various high value chemicals production has been neglected. (ii) The Lurgi fixed-bed coal gasification technique is inefficient with large amount of waste water and waste gas emission. (iii) Heat removal is a significant problem for the fixed-bed LTFT reactor, and the circulating fluidized-bed HTFT reactor is confronted with many operational disadvantages. Recently, advanced coal gasification technique and FT reactors have been developed. The entrained flow bed coal gasification technique is well developed, which is characterized with high carbon conversion and much less waste water and waste gas emission[4, 5]. With nearly isothermal operation of the catalytic bed, the slurry LTFT reactors has been developed and commercialized with a number of advantages over the fixed bed reactor[6, 7]. The operational disadvantages of circulating fluidized-bed HTFT reactor have been overcome by the development of the fixed fluidized-bed reactor, which is relatively easy to operate and more economic, and shows other advantages, such as excellent isothermal characteristics, higher pass per conversion, and lower catalyst consumption[8, 9]. However, there is still no investigation on high value chemicals production as regards the integrated HTFT-LTFT system.

To solve the problem mentioned above, the novel integrated HTFT-LTFT system is proposed based on the advanced coal gasification and FT techniques. The key feature of the proposed system is the high value chemical production. Light olefins and α-olefins are produced to take advantage of the high olefin content characteristic in the HTFT and LTFT syncrude. In this paper, we investigate three integrated HTFT-LTFT systems with different FT wax upgrading approaches. The systems are modelled in Aspen Plus software. And thermodynamic analysis and a detailed economic analysis is performed to guide technology selection and research efforts towards more efficient HTFT-LTFT systems. The synergies of the integrated system is also discussed compared with HTFT/LTFT system with the separated HTFT process and LTFT process.

2. Integrated HTFT-LTFT system and plant modeling

2.1. Integrated HTFT-LTFT system description

Fig. 1(a) illustrates the HTFT-LTFT integrated system including coal gasification and syngas treatment unit, FT synthesis unit, and FT syncrude integrated upgrading unit. The Texaco entrained flow coal gasification technology is considered for syngas production in this article not only because of the low emission and economic benefits, but also