CHEMICAL ENGINEERING RESEARCH AND DESIGN 90 (2012) 383–396

Contents lists available at ScienceDirect

Chemical Engineering Research and Design

journal homepage: www.elsevier.com/locate/cherd

A novel slurry bubble column membrane reactor concept for Fischer–Tropsch synthesis in GTL technology

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ABSTRACT

Fischer–Tropsch synthesis (FTS) plays an important role in the production of ultra-clean transportation fuels, chemicals, and other hydrocarbon products. In this work, a novel combination of fixed-bed and slurry bubble column membrane reactor for Fischer–Tropsch synthesis has been proposed. In the first catalyst bed, the synthesis gas is partially converted to hydrocarbons in a water-cooled reactor which is fixed bed. In the second bed which is a membrane assisted slurry bubble column reactor, the heat of reaction is used to preheat the feed synthesis gas to the first reactor. Due to the decrease of H_2/CO to values far from optimum reactants ratio, the membrane concept is suggested to control hydrogen addition. A one-dimensional packed-bed model has been used for modeling of fixed-bed reactor. Also a one-dimensional model with plug flow pattern for gas phase and an axial dispersion pattern for liquid-solid suspension have been developed for modeling of slurry bubble column reactor. Proficiency of a membrane FTS reactor (MR) and a conventional FTS reactor (CR) at identical process conditions has been used as a basis for comparison in terms of temperature, gasoline yield, H_2 and CO conversion as well as selectivity. Results show a favorable temperature profile along the proposed concept, an enhancement in the gasoline yield and, thus a main decrease in undesirable product formation. The results suggest that utilizing this type of reactor could be feasible and beneficial. Experimental proof of concept is needed to establish the validity and safe operation of the proposed reactor.

Keywords: Bubble column; Slurry reactor; Fischer–Tropsch synthesis; Hydrogen-permselective membrane; GTL technology

1. Introduction

1.1. *GTL technology*

Recently, the high oil price has created considerable interest in the development of alternative technology for the manufacture of transportation fuels. Natural gas in remote areas can be converted to shippable liquid fuels (e.g., gasoline, diesel, and wax) through the gas-to-liquid (GTL) process (Schulz, 1999; Hall, 2005). In the GTL process, Fischer–Tropsch synthesis (FTS) is the key technology for converting synthesis gas (mixture of CO and H_2) to liquid fuels. The development of an effective catalyst and reactor system is the most competitive issue in FTS. Owing to the high demand on gasoline in the world and its higher price relative to that of diesel, production of gasoline from the FT process becomes more favorable. FTS is either low temperature process (LTFT) or high temperature process (HTFT) depending on the product required. High temperature process operates at 300–350 °C on Fe-based catalysts and is mainly used for the production of $C5^+$ and linear olefins while the low temperature process operates at 200–240 °C and is applied for the production of waxy material (Akhtar et al., 2006). The various types of reactors (including fixed-bed, fluidized bed, and slurry phase) have been considered in the history of FTS process development, characterizing with the most suitable particle size of the catalyst used (Wang et al., 2003).

Abbreviations: CR, conventional reactor; FMDR, fluidized-bed membrane dual type reactor; FTS, Fischer–Tropsch synthesis; HTFT, high temperature Fischer–Tropsch process; LTFT, low temperature Fischer–Tropsch process.

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Received 13 July 2010; Received in revised form 7 July 2011; Accepted 20 July 2011
0263-8762/$ – see front matter
doi:10.1016/j.cherd.2011.07.014