Fischer-Tropsch

There are several Fischer-Tropsch reactors in operation: multi-tubular fixed bed (trickle flow), fluidized bed / risers and slurry columns. For this workshop we will consider the low temperature (< 260 °C) slurry reactor. We will approach the problem in the simplest way possible while still capturing the essentials.

For simplicity we will only consider the main reaction:

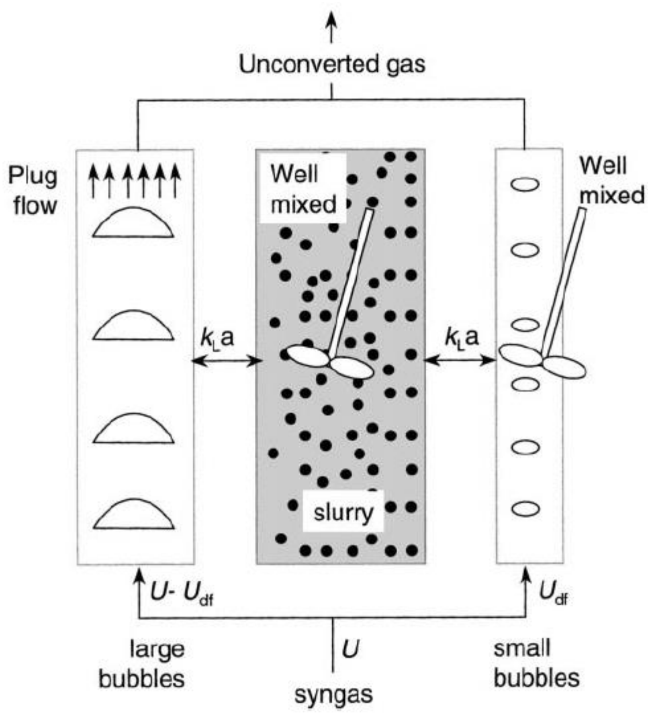
Reaction 1: $CO + 2H_2 \rightarrow CH_2 + H_2O$ $\qquad \Delta H_r = -76 \times 10^3 \ \frac{J}{mol\ H_2}$

The reaction rate is given by:

$$-R_{CO} = K_r C_{CO}^l = 1.5 \times 10^{-4} C_{CO}^l \qquad \frac{mol\ CO}{kg_{cat} s}$$

C_{CO}^l is the CO concentration in the liquid phase. K_r is determined at 515 K.

For the modelling we use the model proposed by Krishna, which includes the liquid phase, small bubbles and large bubbles. The large bubbles move in plug flow, while the liquid and the small bubbles are close to a CSTR. The latter we will model using the axial dispersion model.



The dense phase consists of the liquid phase plus the catalyst plus the small bubbles. There is a liquid flow through the dense phase (velocity = U_L).

The following correlations can be used:

Rise (linear) velocity of the small bubbles:

$$V_{SB} = 0.095 \times (1 + \frac{0.8\epsilon_p}{0.095})$$

In which ϵ_p is the hold-up of catalyst in the dense phase in m^3 catalyst / m^3 dense phase. The dense phase is the liquid plus catalyst plus the small bubbles.

The hold-up of small bubbles is given by (m^3 small bubble / m^3 dense phase):

$$\epsilon_{SB} = 0.6072 \times (1 - \frac{0.7\varepsilon_p}{0.27})$$

The hold-up of large bubbles is given by (m^3 large bubble / m^3 total volume (small bubbles + large bubble + liquid + catalyst)):

$$\epsilon_{LB} = 0.7 \times U_{LB}^{0.58}$$

In which U_{LB} is the superficial velocity of the large bubbles.

For $k_l a$ the following relations hold:

$$kla_{LB} = 2.25\epsilon_{LB}, \;\; kla_{SB} = 4.5\epsilon_{SB}$$

Assignment:

Design a slurry reactor system for the production of 6000 ton / day CH_2. T = 515 K, P = 30 bar.
You may use a constant gas velocity and work with an isothermal model. Do calculate how many vertically placed cooling tubes of 2 inch are required (cooling medium = 500K). Investigate numerically the effects of mixing in the liquid phase.
For the modelling you may get inspired by the bubble column model of last week.

Restrictions:
Maximal reactor diameter = 8 m
Maximal reactor height = 30 m
Maximal catalyst hold-up, ϵ_p = 0.3
Maximal superficial gas velocity = 0.4 m/s

Other parameters:
You can use a superficial liquid velocity of 0.01 m/s
Catalyst density = 2000 kg/m^3 catalyst
No restriction to mass transfer in the gas phase
The equilibrium distribution for CO is 2.5 (C^g/C^l) [take a careful look at the definition]
Information on dispersion coefficients: see slides on bubble & slurry reactors
Information on heat transfer coefficients: see slides on bubble & slurry reactors