

Regenerator of a Catalytic Cracking Unit

In the regenerator of a catalytic cracking unit the catalyst is regenerated by combustion of the coke deposited on the catalyst. The regenerator is a bubbling fluidized bed reactor. You are asked to design (size) a regenerator with the following characteristics:

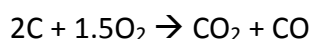
1. The temperature inside the regenerator is spatially uniform at 900 K (you may use an isothermal model)
2. The operating pressure is 1 bar
3. Air is used for the combustion
4. The catalyst feed rate is 600 kg / s
5. The concentration coke on catalyst (C_c) of the inlet stream is 1 mol coke per kg catalyst (1 mol coke / kg_{catalyst})

Your design has to meet the following demands:

1. The conversion of coke has to be in the range of 45% to 55%
2. The conversion of oxygen has a upper limit of 70%
3. The superficial gas velocity (u_0) has an upper limit of 1 m/s

You may use the following relations and assumptions:

- The reaction that is proceeds is:



- The reaction rate is describe by:

$$-R_{O_2} = k \cdot \rho_{catalyst} \cdot C_c \cdot C_{O_2} \left[\frac{mol O_2}{m^3_{reactor} \cdot s} \right]$$

With:

C_c in mol C / kg_{catalyst}, C_{O_2} in mol O₂ / m³_{gas}, $\rho_{catalyst}$ in kg_{catalyst} / m³_{reactor},

k in m³_{gas}/(mol C . s)

$\rho_{catalyst} = 500 \text{ kg}_{catalyst} / m^3_{reactor}$

- The rate constant k in the equation above is given by (T in K):

$$k = 10^9 e^{\frac{-18889}{T}}$$

- Oxygen transfer from the bubble to the dense phase can be described by a constant height of a transfer unit (H_T)

$$H_T = \frac{u_0}{K_m} = 1 * H^{0.5} * d_t^{0.42} (m)$$

In which K_m is in m^3/s gas transferred between bubble and dense phase per m^3_{reactor} , H is the height of the bed and d_t the diameter of the bed (both in m)

- For the hydrodynamics you may assume:
 - a. Gas bubbles in plug flow
 - b. Gas in the dense phase well mixed (CSTR)
 - c. Solids well mixed (CSTR)

Furthermore, you may find inspiration in the lectures on the VanDeemter model.

Questions:

- How much air is required (in kg/s)? Take 50% conversion of coke and 50% conversion of oxygen
- Write a reactor model on basis of which the regenerator can be sized
- Present your design; give:
 - a. The overall mass balance (input – output) over coke and oxygen
 - b. The superficial velocity
 - c. The concentration of coke on catalyst ($\text{mol C} / \text{kg}_{\text{catalyst}}$) in the reactor
 - d. Axial profiles of oxygen in the bubble and dense phase
 - e. The diameter en length of the reactor.