Fluidized bed modelling

Catalytic reaction

Reacting solid (FCC regenerator)

Catalytic reaction, 1st order

$$\frac{dC^b}{d\theta} = -N_T\left(C^b - C^d\right)$$

$$0 = \frac{1}{N_E}\frac{d^2C^d}{d\theta^2} + N_T\left(C^b - C^d\right) - N_R C^d$$

$$\frac{dC^b}{d\theta} = -N_T\left(C^b - C^d\right)$$

$$\frac{d^2C^d}{d\theta^2} = -N_T N_E\left(C^b - C^d\right) + N_R N_E C^d$$

$$N_T = \frac{k_m L}{U_0} \qquad N_E = \frac{U_0 L}{D_e} \qquad N_R = \frac{K_r \rho_c f_s L}{U_0}$$

Boundary conditions:

$$\theta = 0 \rightarrow C^b = C^b_{in} \quad \& \quad \frac{dc^d}{d\theta} = 0$$

$$\theta = 1 \rightarrow \quad \frac{dc^d}{d\theta} = 0$$

Numerical approach

- 2^{nd} order differential equation
  - Order reduction
- Boundary value problem
  - BVP4C

Matlab code (try this yourself)

```
% Cdense = y(1)
% dCdense/dx = y(2)
% Cbubble = y(3)
```

Definition of the y vector

```
 function dydx = f(x,y)
   dydx = [
                ];
 end
```

The differential equations in vector form

```
function res = mat4bc(ya,yb)
res = [  ya(2)
        yb(2)
        ya(3)-Cbin];
end
```

The boundary conditions

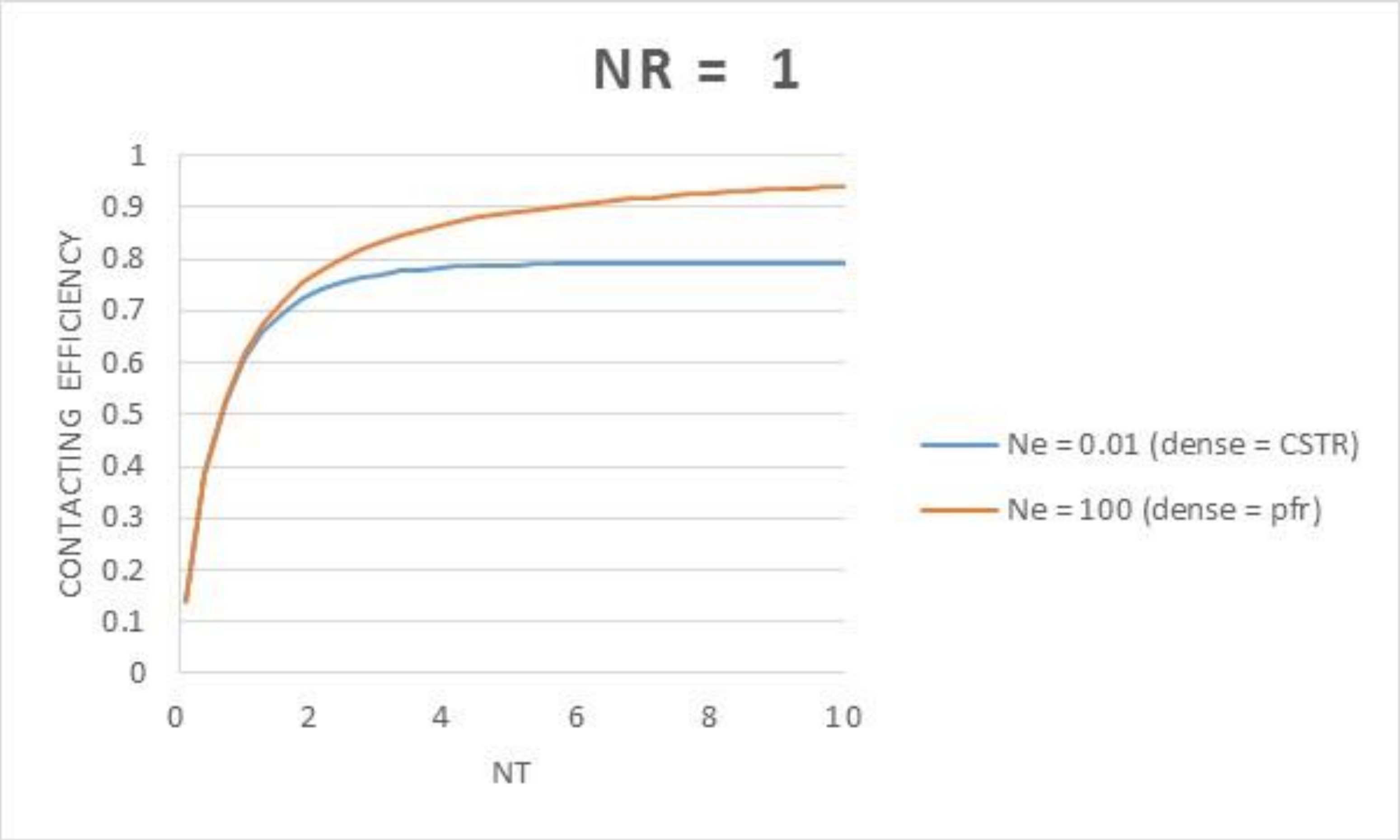
Let’s play around with the code

The code also calculates the conversion of an equivalent PFR and CSTR reactor.

Vary N_T , N_E and N_R and see their effect the gas-solid contacting.

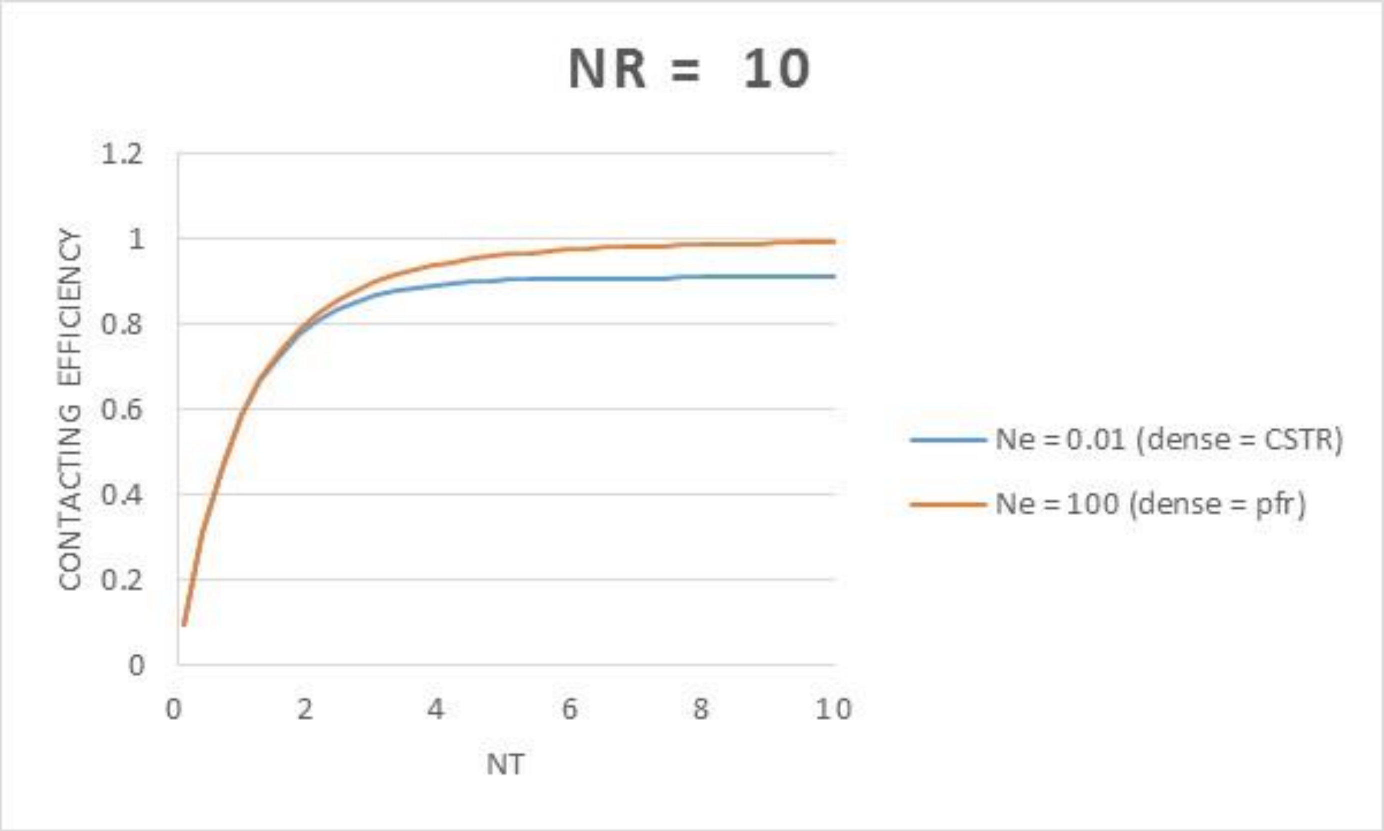
Contacting efficiency

$$\eta = \frac{X}{X_{pfr}} \; at\ equal\ N_r$$



Contacting efficiency

$$\eta = \frac{X}{X_{pfr}} \; at\ equal\ N_r$$



Contacting efficiency

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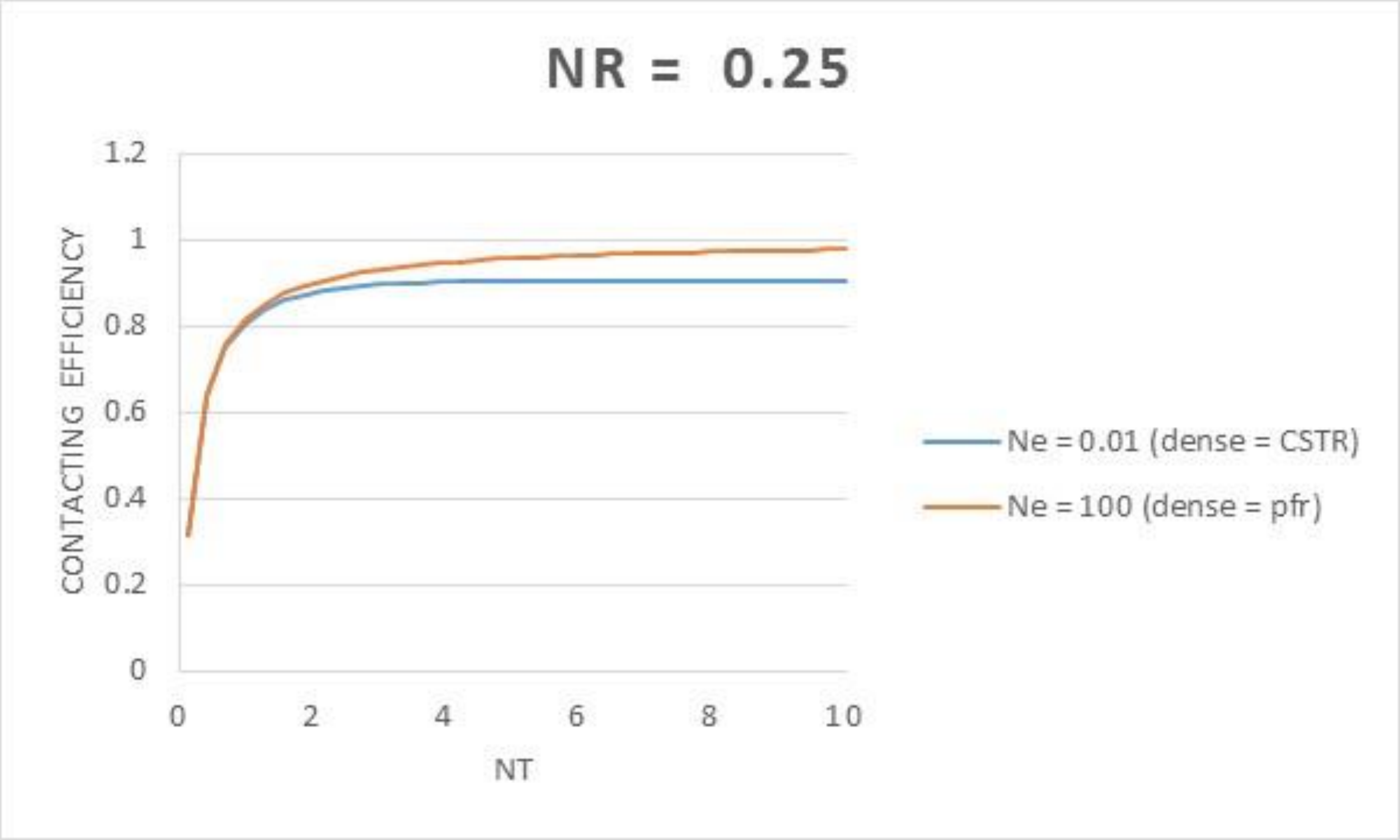


A reacting solid

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:

Reaction kinetics

- The reaction that is proceeds is:

  $2C + 1.5O_2 \rightarrow CO_2 + CO$

- The reaction rate is describe by:

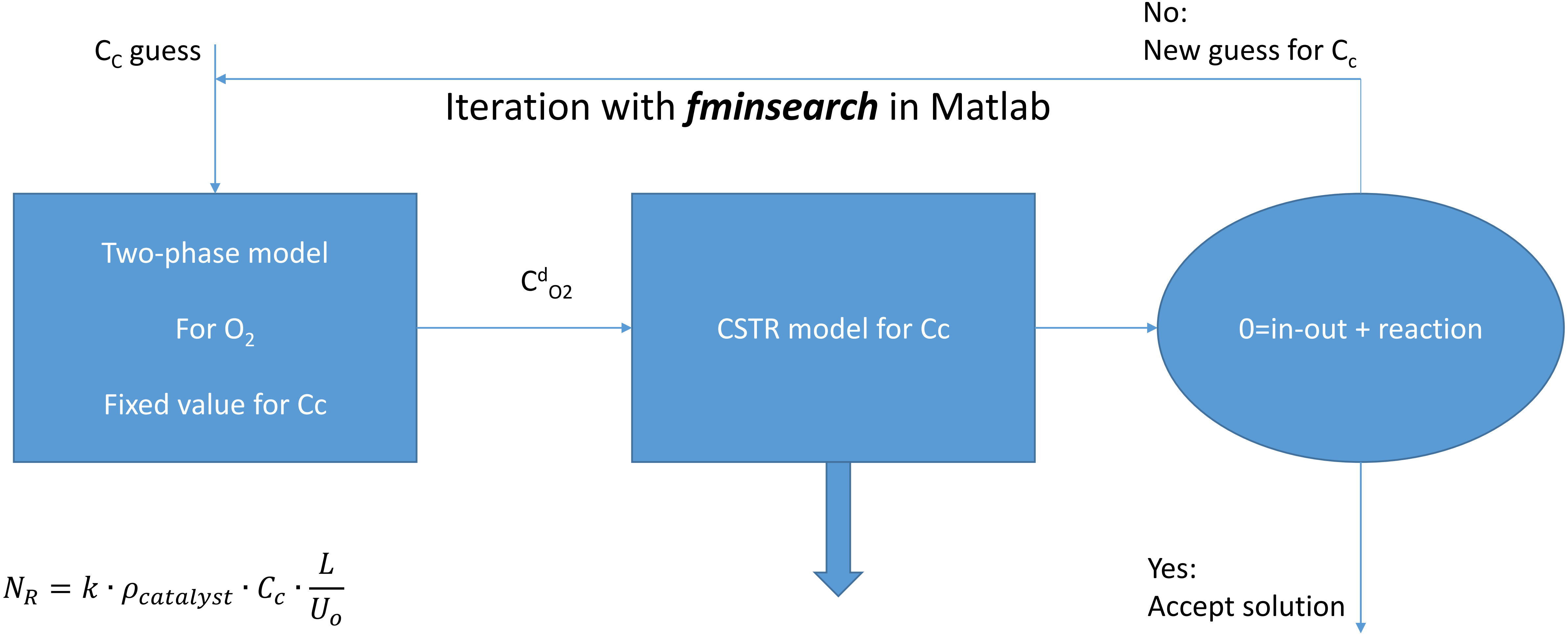
$$-R_{O_2} = k \cdot \rho_{catalyst} \cdot Cc \cdot C_{O_2} \ [\frac{mol\ O_2}{m^3_{reactor} \cdot s}]$$

With:

Cc in mol C / $kg_{catalyst}$, C_{O2} in mol O_2 / $m^3{}_{gas}$, $\rho_{catalyst}$ in $kg_{catalyst}$ / $m^3{}_{reactor}$,

k in $m^3{}_{gas}$/(mol C . s)

Modelling approach



$$N_R = k \cdot \rho_{catalyst} \cdot C_c \cdot \frac{L}{U_o}$$

$$0 = \theta_m C_C^{in} - \theta_m C_c - \frac{4}{3} k \cdot \rho_{catalyst} \cdot C_c \cdot C_{o2}^d \cdot V_{reactor}$$

FCC regenerator

- Read the assignment
- Design the reactor