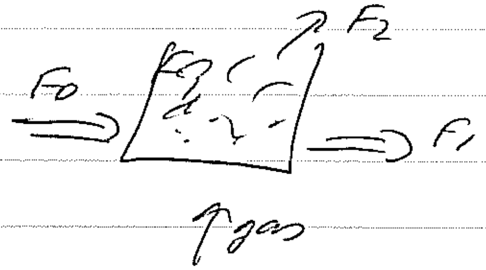
Mixed gas flow & solids flow reactor with Elutriation



$$F_1 = \sum F_1(R_i)$$

$$F_0(R_i) = F_1(R_i) + F_2(R_i)$$

$$\underline{F_2(R_i) = \kappa(R_i)\, W(R_i)}$$

$$\frac{F_1(R_i)}{W(R_i)} = \frac{F_1}{W}$$

same for all particles

assuming well mixedness

$$F_0(R_i) = F_1(R_i) + \kappa(R_i)\frac{W}{F_1}F_1(R_i)$$

$$F_0(R_i) = F_1(R_i)\left[1 + \kappa(R_i)\frac{W}{F_1}\right]$$

(*) $$\boxed{F_1 = \sum F_1(R_i) = \sum \frac{F_0(R_i)}{1 + \kappa(R_i)\frac{W}{F_1}}}$$

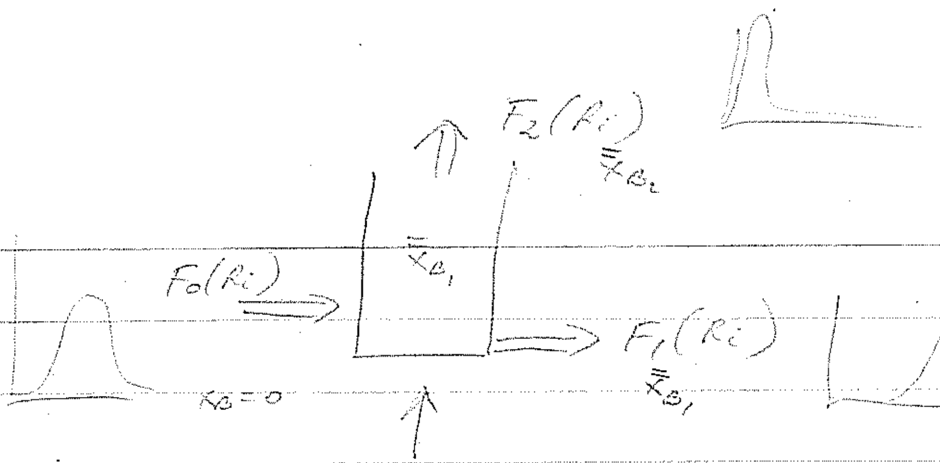
$$\bar{t}(R_i) = \frac{W(R_i)}{F_1(R_i) + F_2(R_i)} = \frac{1}{\frac{F_1}{W} + \kappa(R_i)}$$

$$F_2(R_i) = \kappa(R_i)\frac{F_1(R_i)}{F_1}W = \kappa(R_i)\, W(R_i)$$

$$1 - \bar{X}_B(R_i) = \int_0^{\tau} [1 - X_B(R_i)]\, E(t)\, dt$$

$$1 - \bar{\bar{X}}_B = \sum \left(1 - \bar{X}_B(R_i)\right)\frac{F_0(R_i)}{F_0}$$

Approximate t_s = const



All solids have exponential RTD but their mean residence time depends on size

(1) $F_0 = F_1 + F_2$

(2) $F_0(R_i) = F_1(R_i) + F_2(R_i)$

perfect mixing among them: requires

(3) $\left| \dfrac{F_1(R_i)}{F_1} = \dfrac{W(R_i)}{W} \right| \Rightarrow$ size distributions are the same

Different $\bar{t}(R_i)$ for various R_i

(4) $\bar{t}(R_i) = \dfrac{W(R_i)}{F_0(R_i)} = \dfrac{W(R_i)}{F_1(R_i) + F_2(R_i)} = \dfrac{1}{\dfrac{F_1}{W} + \dfrac{F_2(R_i)}{W(R_i)}}$

(5) $1 - \bar{x}_B(R_i) = \displaystyle\int_0^{\tau(R_i)} [1 - x_B(R_i)] \frac{e^{-t/\bar{t}(R_i)}}{\bar{t}(R_i)}\, dt$ $\qquad \bar{t}(R_i) = \dfrac{1}{\frac{F_1}{W} + \kappa(R_i)}$

$1 - \bar{\bar{x}}_B = \displaystyle\sum^{R_m} [1 - \bar{x}_B(R_i)] \frac{F_0(R_i)}{F_0}$ $\qquad$ as $R_i \downarrow$ $\kappa(R_i) \uparrow$, $\bar{t}(R_i) \downarrow$

$-\dfrac{d(\text{no of these particles})}{dt} = \kappa(\text{number of these particles})$

$\kappa \sim \dfrac{(\text{gas velocity})^4}{(\text{bed height})(\text{particle size})^{2 \text{ to } 3}}$

$\kappa(R_i) = \dfrac{F_2(R_i)}{W(R_i)}$ $\qquad \bar{t}(R_i) = \dfrac{1}{\frac{F_1}{W} + \kappa(R_i)} = \dfrac{W(R_i)}{F_0(R_i)}$

(*) $F_1 = \displaystyle\sum^{R_m} F_1(R_i) \overset{\text{from (3)}}{=} \sum \frac{F_1}{W} W(R_i) \overset{\text{from (4)}}{=} \sum \frac{F_1}{W} \frac{F_0(R_i)}{\frac{F_1}{W} + \kappa(R_i)} = \sum \frac{F_0(R_i)}{1 + \frac{W}{F_1}\kappa(R_i)}$

$F_1 = \displaystyle\sum^{R_m} \frac{F_0(R_i)}{1 + \frac{W}{F_1}\kappa(R_i)}$ $\qquad$ Trial & error $\qquad F_1(R_i) = \dfrac{F_0(R_i)}{1 + \frac{W}{F_1}\kappa(R_i)}$

(over)

Given: $F_0(R_i)$, W, $x(R_i)$

solve for F_1 by trial and error from (*)

i.e. guess F_1. get $F_1(R_i)$ and sum to get F_1.

Then

$$\begin{pmatrix}\text{fraction of}\\ \text{all solids unconverted}\end{pmatrix} = \sum_{\text{all sizes}} \begin{pmatrix}\text{fraction}\\ \text{of size } R_i\\ \text{unconverted}\end{pmatrix}\begin{pmatrix}\text{fraction of}\\ \text{that size}\\ \text{in the feed}\end{pmatrix}$$

$$1-\bar{\bar{X}}_B = \sum_{R_i=R_{min}}^{R_{max}} \left[1-\bar{X}_B(R_i)\right] \frac{F_0(R_i)}{F_0}$$

This means that conversion is defined on total solids:

$$\bar{\bar{X}}_B = \frac{F_{B0} - (F_{1B} + F_{2B})}{F_{B0}}$$

This can be written as:

$$1-\bar{\bar{X}}_B = \frac{F_1(1-\bar{\bar{X}}_{Bov}) + F_2(1-\bar{\bar{X}}_{Bel})}{F_0}$$

where

$$1-\bar{\bar{X}}_{Bov} = \sum_{R_i=R_{min}}^{R_{max}} \left[1-\bar{X}_B(R_i)\right] \frac{F_1(R_i)}{F_1}$$

$$1-\bar{\bar{X}}_{Bel} = \sum_{R_i=R_{min}}^{R_{max}} \left[1-\bar{X}_B(R_i)\right] \frac{F_2(R_i)}{F_2}$$

$$\bar{\bar{X}}_{Bov} = \frac{F_1 - F_{1B}}{F_1} \qquad F_{1B} = F_1(1-\bar{\bar{X}}_{Bov})$$

Same problem can be approached from the point of view of cavitation size distribution

$$p_0(R) \neq p_1(R) = p_R(R) \neq p_2(R)$$

$$F_1(R) = F_1\, p_1(R)\, dR$$
$$w_\phi(R) = w \cdot p_R(R)\, dR$$