EXPERIMENT No. 5

Residence time distribution in a Tubular Vessel

Objective:

(1) To construct C curve for pulse input
(2) To plot age-distribution curve (E vs t)
(3) To calculate average residence time
(4) To calculate the vessel dispersion number (D/uL) for three different flow rates

Theory:

Real reactors never fully follow the two idealized flow patterns, plug flow and mixed flow. The deviation from the ideal flow patterns can be determined by the residence time distribution.

According to Fick's Law for molecular diffusion, in the x-direction the differential equation is $\frac{\partial C}{\partial t} = D\frac{\partial^2 C}{\partial x^2}$

where D is the axial dispersion coefficient

In dimensionless form using z = x/L and θ = t / ṫ = tu/L, the above equation becomes

$\frac{\partial C}{\partial \theta} = \left(\frac{D}{uL}\right)\frac{\partial^2 C}{\partial z^2} - \frac{\partial C}{\partial z}$ Where the dimensionless group D/uL is called vessel dispersion number, is the parameter which measures the extent of axial dispersion.

For $\frac{D}{uL} \to 0,$ negligible dispersion, plug flow

For $\frac{D}{uL} \to \infty,$ large dispersion, mixed flow

For closed vessel $\frac{D}{uL}$ can be determined by following equation-

$$\sigma_\theta{}^2 = 2\frac{D}{uL} - 2\left(\frac{D}{uL}\right)^2 (1 - e^{-\frac{uL}{D}})$$

Where $\sigma_\theta{}^2 = \frac{\sigma^2}{\dot{t}^2}$, $\sigma_\theta{}^2 = \frac{\sum t_i{}^2 C_i}{\sum C_i} - \dot{t}^2$ and $\dot{t} = \frac{\sum t_i C_i}{\sum C_i}$

Apparatus:

(1) One tubular vessel (L= 81.5 cm) packed with Raschig rings
(2) Dye injection system
(3) Stop Watch and test tubes
(4) Colorimeter

Procedure:

(i) Start the water flow by adjusting the valve and metered by the calibrated rotameter.
(ii) Inject the dye (about 5 ml of methylene blue) by the hypodermic syringe through the injection port near the inlet.
(iii) Collect 10-12 samples from the outlet in different test tubes at one minute interval (approx).
(iv) Analyze the sample by a spectrophotometer at 664 nm.
(v) Calculate vessel dispersion number from average residence time and variance.
(vi) Plot E Curve and C curve
(vii) Plot D/uL as a function of Reynold's Number (dia : 5 cm)