

CHEMMAT 361/704

Mixing in Fermentors

Purposes of mixing

- Maintain homogeneity
- Keep cells suspended
- Facilitate mass transfer

Mixing Types

- Dispersion
- Diffusion
- Distribution
 - Convective
 - Can be slow in large tanks
 - “Macromixing”

Analysis of Mixing

- Measured by tracer response techniques
- Typical tracers
 - Acid, Base, Salts, Dyes, Hot liquid
- Two parameters
 - Mixing intensity (how much)
 - Mixing time (how long)

Estimation of Mixing Intensity

- Measure of deviation from completely mixed
- Arbitrary scale
- Intensity given by:

$$\text{Intensity} = \frac{C(\infty) - 0.5\Delta C}{C(\infty)} \times 100\%$$

Estimation of Mixing time

- $t_m = f(V, N_i, \mu, D_i)$
- Can correlate with Reynolds number for mixing:

$$\text{Re} = \frac{D_i^2 N_i \rho}{\mu}$$

- For $\text{Re} > 5000$ mixing time is constant.

$$N_i t_m = \frac{1.54V}{D_i^3}$$

- For $\text{Re} < 5000$ Mixing time increases rapidly with decreasing Re
- Mixing time doubled by aeration

Power required for mixing - Ungassed Newtonian fluids

- Parameters linked by power number N_p which is a function of Reynolds number

$$N_p = \frac{P}{\rho N_i^3 D_i^5}$$

- For laminar flow

$$N_p \propto \frac{1}{Re} \quad P = k_1 \mu N_i^2 D_i^3$$

- For turbulent flow

$$P = N_p' \rho N_i^3 D_i^5$$

- Baffles increase the value of N_p' by a factor of between 2 and 10

Power required for mixing - Ungassed Non-newtonian fluids

- Difficult to quantify
- Power delivery often not uniform throughout fermentor
- Use Reynolds number based on apparent viscosity. K is the consistency index. For turbine impellers k is about 10

$$Re_i = \frac{N_i^{2-n} D_i^2 \rho}{k^{n-1} K}$$

Power required for mixing - Gassed fluids

- Gassing reduces power requirements through reduced resistance caused by gas cavities
- Power reduction is poorly understood often expressed as ratio to ungassed power requirement

$$\frac{P_g}{P_0} = 0.10 \left(\frac{F_g}{N_i V} \right)^{-0.25} \left(\frac{N_i^2 D_i^4}{g W_i V^{2/3}} \right)^{-0.20}$$