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Process Chem and Pharmaceutical Engineering 1

Mixing and Agitation

Wan Nurul Huda binti Wan Zainal
Faculty of Engineering Technology
wannurulhuda@ump.edu.my

Chapter Description

- Aims
  - Apply the knowledge of mass balance and mass transfer in separation process

- Expected Outcomes
  - Distinguish between positive, negative and neutral mixing
  - Describe the mechanism and kinetic of mixing
  - Comprehend the applications of mixing

- References
  - Unit Operations of Chemical Engineering, Warren L. McCabe, Julian C. Smith and Peter Harriott, McGraw Hill International Edition, 7th Edition, 2005
  - Pharmaceutics – I, P.V. Kasture, S.R. Parakh, S.A. Hasan, S.B. Gokhale, Nirali Prakashan, 15th Edition, 2008.

Introduction

- Mixing involves gases, liquids or solids in any proportion and involves two or more number components.

- Definition of mixing: the process in which two or more ingredients are treated so that every particle of any one ingredient lies as near as possible to the particle of the other ingredient.

Source : Unit Operations of Chemical Engineering

Difference between Agitation and Mixing

Agitation: induced motion of a material in a specified way, usually in a circulatory pattern inside some sort of container.

Mixing: random distribution, into and through one another, of two or more initially separate phases.

Purpose of Mixing

- Mixing may affect the efficacy of the preparation. It has bearing on the stability of certain formulations.
- Purpose of mixing:

Uniformity of composition in any part of a mixture of bulk	To promote physical or chemical reactions like diffusion, dissolution, etc.

Scale of Scrutiny

- Describe the minimum size of the regions of segregation in a particular mixture (insufficiently mixed)
- 0.1 g of A mix with 0.1 g of B will produce 0.2 g of mixtures.
- To describe the degree of unmixedness:
- a) The scale of segregation (how big is the segregation area)
- b) The intensity of segregation
- The scale of segregation: A measure of the size of the regions of unmixed materials
- A high intensity of segregation can be tolerated as long as the scale of segregation is small

Type of Mixing

- Mixing can be classified into:

Positive mixing: in a given time, the components **completely** and **spontaneously mix** with each other.

Example: mixing of gases or miscible liquids

Negative mixing: in a two phase systems, when the phases differ in densities, it separates – unless it is continuously agitated.

Example: suspension of a solid in a liquid

Neutral mixing: when neither mixing nor demixing takes place, unless the system is acted upon by a system of forces.

Example: mixing of solids and liquids, when solid concentration is high.

Degree of Mixing

- Measured by the statistical variation in composition of a number of samples drawn from the mixture.
- Index of mixing:
- $M = \frac{Sr}{S}$
- Where Sr = a series of samples drawn from a random mix
- S= standard deviation of samples drawn from the mixture under examination.

Mechanism of Mixing

- Mixing can be achieved by any of the following mechanisms:

Convective mixing: movement of a group of particles from one place in the powder bed to another

Diffusive mixing: distribution of particles over a newly developed surface

Shear mixing: formation of slip planes within the bulk

Factors Affecting Mixing

Volume – adequate space

Handling of mixer -

Duration of mixing - optimum

Mixer mechanism

Rate of Mixing

- Mixing is a process used for achieving uniform randomness.
- The rate of mixing is proportional to the amount of mixing to be done.
- $\frac{dM}{dt} = k(1 - M)$
- M = index of mixing
- K = rate constant, depends on the physical nature of the materials being mixed and on the geometry and operation of the mixer

Mixing Application

- Miscible liquids are classified as positive and would mix completely without external help at given time.
- The time required for mixing is reduced by agitation during which the scale of segregation is reduced, allowing a fast decay in the intensity of segregation by natural diffusion.
- The impeller causes the liquid to circulate through the vessel and eventually return to the impeller.
- Miscible liquids are commonly mixed by impellers rotating in tanks. These are classified as:
- 1. Paddles
- 2. Propellers
- 3. Turbines

- All the material should pass through the impeller zone at frequent intervals of time, the design of the mixer preventing the formation of ‘dead zones’.
- The turbulent, high- velocity flow of liquid from the impeller causes mixing by projecting eddies into and entraining liquid from the neighbouring zones.
- The flow pattern may be analyzed in three components:

a. Radial flow: In a direction perpendicular to the impeller shaft
b. Longitudinal or axial flow: In a direction parallel to the shaft
c. Tangential flow: The liquid follows a circular path around the shaft

- Tanks with vertical agitators may be baffled by one or more strips mounted vertically on or just away from the vessel wall (Baffle). These reduce tangential flow thus produce additional turbulence.

Paddle Mixer

- Rotate at low speeds (10- 100 rpm)
- - Simple paddle (with upper and lower blades), suitable for mixing miscible liquids of low viscosity [A]
- - The gate paddle [Figure B] is suitable for mixing liquids of higher viscosity
- - The anchor paddle [Figure D] with low clearance between pan and blade is useful for working across heat transfer surface
- - Stationary paddles intermeshing with the moving element suppress swirling in the mixer. Baffles are necessary.

Turbines

- Designs are intermediates between paddles and propellers
- - Are effective mixers over a wide viscosity range and provide a very versatile mixing tool
- - The ratio of radial flow to tangential flow increases as the operating speed increases
- - Baffles must be used to limit swirling unless a shrouded turbine is used

Propeller Mixer

- Commonly used for mixing miscible and immiscible liquids of low viscosity
- Marine propeller is the typical one
- High speed rotation (400- 1500 rpm) of the relatively small element provides high shear rates in the vicinity of the impeller and a flow pattern with mainly axial and tangential components
- May be used in unbaffled tanks when mounted in an off- center position or are inclined from the vertical
- Horizontal mounting in the side of the vessel is frequently used when the scale of the operation is large

Conclusion of The Chapter

This chapter discussed about the difference between mixing and agitation, type of mixing, degree of mixing, mechanism of mixing, rate of mixing, and application of mixing.

Unit Operations of Chemical Engineering, Warren L. McCabe, Julian C. Smith and Peter Harriott, McGraw Hill International Edition, 7th Edition, 2005

Pharmaceutics – I, P.V. Kasture, S.R. Parakh, S.A. Hasan, S.B. Gokhale, Nirali Prakashan, 15th Edition, 2008.