Introduction to unit operations of chemical engineering

Chemical engineering has developed from chemical technology and became an independent brach of knowledge. It is a generalized method of description of processes and equipment of chemical and food technologies. Chemical engineering relies on mathemathics, physics, chemistry and physical chemistry.

Traditional classification of processes:

- mechanical processes
- hydrodynamical processes
- heat transport processes
- mass transport processes (or diffusion separation processes)
- chemical processes
- biochemical and biological processes

Essential processes based on different physical principles:

1) **Transport processes**
    - momentum transport – used in hydrodynamics and fluid flow
    - energy transport – used in description of heat transfer and heat exchangers
    - mass transport – used in diffusion-separation processes
2) **Transformation processes**
    - phase change – used in heat exchange accompanied by boiling or condensation and in mass echange such as distillation, drying
    - chemical reaction – used in description of chemical reactors

Unit operations – involve certain type of processes carried out in a specific equipment

Examples of unit operations:

- milling, grinding – involve mechanical processes
- fluid transportation, filtration settling, fluidization, mixing – involve hydromechanical processes
- heat exhange, evaporation – involve energy (heat) transport
- extraction, absorption, drying, distillation, membranes – involve mass transport
- reactors, bioreactors – involve chemical reaction

Another classification of processes:

batch (discontinual) processes – occur in a closed system (such as batch reactor)

combined (semibatch) processes – occur in a system open to a part of mass and closed to another part (such as a drier with a batch of material dried by air flowing through)

continual (flow) processes – occur in an open system (such as a flow-through reactor, pipe, rectification column, etc.)

System – an arbitrary object or its part, or a set of objects set out for analysis. A system is separated from its surroundings by boundaries, which circumscribe the system. Boundaries may be real (e.g. walls,

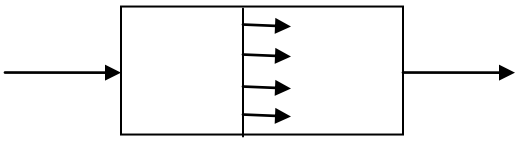
interfaces) or imaginary. They can be fixed or moving. A system can often be conveniently decomposed into subsystems (e.g. an absorption column may contain stages (=plates))

- **Open system** – mass can be transferred across its boundaries
- **Closed system** – mass cannot cross its boundaries but massless transfer of energy (mostly as heat or work) is permitted
- **Isolated system** – neither mass nor energy can be transferred across boundaries
- **Adiabatic system** – heat cannot be transferred across boundaries

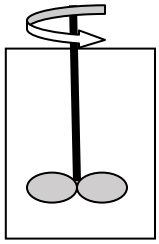
Steady state – local properties within the system do not depend on time (properties such as density, velocity, composition, ...)

Unsteady state, unsteady regime – the state of system is varying in time

Plug flow – small elements of the fluid (called particles of continuum, they are still macroscopic) in a flow-through system remain in the system for the same time (called a residence time). Particularly, in a pipe, all particles travel at the same velocity v



Ideal mixing – all particles have the same probability of occurring anywhere in a vessel (usually stirrred)



Methods of chemical engineering

1) **Formulation of a physical model** – selection of processes and unit operatios needed to describe the system
2) **Formulation of a mathematical model** – balance equations (mass, energy, momentum), equations of state, equilibrium a kinetic relations, deffinition relations
3) **Solution of the mathematical model** – by hand, by computer programs