THAPAR INSTITUTE
OF ENGINEERING & TECHNOLOGY
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Mass Transfer-I

Mass Transfer Equipment (Continue…)

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Mass Transfer Equipment (Continue…)

Agitated vessels

Agitation refers to forcing a fluid by mechanical means to flow in a circulatory or other pattern inside a vessel.

Agitation is the induced motion of a material

Mixing usually implies the taking of two or more separate phases, such as a fluid and a powdered solid or two fluids, and causing them to be randomly distributed through one another.

Mixing is the random distribution of two initially separate phases

- Many operations depend upon effective agitation and mixing of components
- A single homogeneous material such as water in a tank can be agitated but not mixed until another material is added to tank
- Agitation is a means whereby mixing of phases can be accomplished and by which mass and heat transfer can be enhanced between phases or with external surfaces

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- Mixing is concerned with all combinations of phases of which the most frequently occurring ones are
  1. GASES WITH GASES
  2. GASES INTO LIQUIDS: DISPERSION
  3. GASES WITH GRANULAR SOLIDS: FLUIDIZATION, PNEUMATIC CONVEYING, DRYING
  4. LIQUIDS INTO GASES: SPRAYING
  5. LIQUIDS WITH LIQUIDS: DISSOLUTION, EMULSIFICATION, DISPERSION
  6. LIQUIDS WITH GRANULAR SOLIDS: SUSPENSION
  7. PASTES WITH EACH OTHER AND WITH SOLIDS
  8. SOLIDS WITH SOLIDS: MIXING OF POWDERS
- Interaction of gases, liquids, and solids also may take place

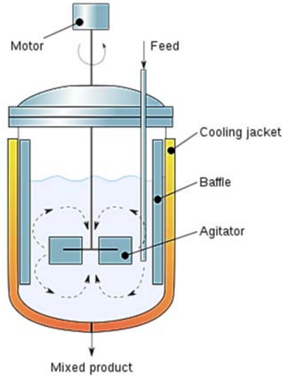
Example: Hydrogenation of liquids in the presence of a slurred solid catalyst where the gas must be dispersed as bubbles and the solid particles must be kept in suspension

Purpose of Agitation

- Suspending of solid particles in a liquid
- Blending of miscible liquids e.g. methanol-water
- Dispersing a gas through a liquid in the form of small/fine bubbles-such as oxygen from air in a suspension of microorganisms for fermentation or for the activated sludge process in waste treatment
- Dispersing a second liquid, immiscible with first to form an emulsion or suspension of fine drops
- Dissolving solids in liquids, such as salt in water.
- Suspending of fine solid particles in a liquid, - in the catalytic hydrogenation of a liquid, solid catalyst particles and hydrogen bubbles are dispersed in the liquid.
- Agitation of the fluid to increase heat transfer between the fluid and a coil or jacket in the vessel wall.

Agitated Vessels

- The schematic of an agitated vessels is shown in the figure
  - An agitator with a suitable impeller
  - Inlet and outlet nozzles
  - Baffles
  - Round bottom to eliminate corners and to avoid the formation of dead zones
  - Impeller is mounted on a shaft
  - Shaft driven by a motor
  - Baffles to reduce tangential motion of fluid
  - A drain and a vent
  - A manhole for the purpose of cleaning & maintenance



https://www.aiche.org/academy/courses/ela116/fluid-mixing-technology-operators

- A stuffing box, or preferably a 'mechanical seal', is used to prevent the leakage of the gas at the top where the shaft enters the vessel.
- The shaft is held by bearings at the gear box and at the shaft seal

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- The agitator motor may be supported on I-beams mounted on the vessel itself.
- A gear box is used to maintain the required speed of the shaft.
- An agitated vessel for gas absorption contains a few 'internals' such as the gas sparger, baffles, and an agitator shaft with impellers.
- The gas is sparged below the impeller mid way between the centre and the periphery of the impeller. It is dispersed in the form of small bubbles by the shear stress created by impeller rotation. This greatly increases the gas-liquid interfacial area of contact and also the mass transfer coefficients.
- A variety of impeller designs are available. The turbine, disk and paddle type impellers are more common.
- Vertical baffles are used to prevent the formation of a vortex at the free liquid surface. The baffles also help to increase the turbulence in the tank.
- Thin metal plates having a width equal to 8 to10% of the tank diameter, spot-welded to the tank, act as the baffles.

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- The power input to the impeller depends upon a number of factors such as the impeller design and rpm, liquid properties, the gas rate, and the presence of suspended solids, etc.
- The impeller is usually located at about1/3 of the liquid depth from the bottom.
- The superficial gas velocity is kept-low in range the range of 0.1 to 0.25 ft/s.
- The impeller tip speed may be as high as 50 ft/s.
- Agitated vessels are used when the dissolved gas undergoes a chemical reaction in the liquid. This vessel is not used for physical absorption since 'back-mixing' in the liquid phase substantially reduces the mass transfer driving force.
- Hydrogenation of vegetable oils in the presence of suspended nickel catalyst, absorption of carbon dioxide in a lime slurry to make precipitated calcium carbonate, liquid-phase oxidation and chlorination in organic synthesis, etc. is a few common cases of application.

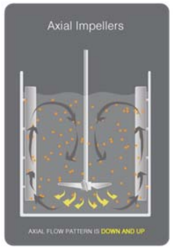
Impellers

As per flow direction impellers are of two types

1. **Axial flow impellers**
2. **Radial flow impellers**

Axial flow impellers:

- Axial (down and up) pumping is an important flow pattern because it addresses two of the most common challenges in mixing
  - i. Solid suspension
  - ii. Stratification
- In this process both the superficial and annular velocities can be calculated to determine and control the level of mixing.
- Some of the axial flow impellers are
  - o Hydrofoil
  - o Axial flow turbine
  - o Helical
  - o Propeller, etc.



https://www.dynamixinc.com/mixing-101-the-basic-principles-of-mixing-and-impellers

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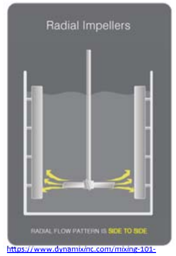
Radial flow

- Unlike axial impellers, radial impellers are commonly selected for low level mixing (known as a tickler blade) or elongated tanks.
- They typically give high shear rates because of their angle of attack.
- They also have a relatively low pumping number, making them the most sensitive to viscosity.
- Radial impellers do not have a high tank turnover flow like axial flow impellers.
- Some of the radial flow impellers are
  - o Ruston turbine
  - o Parabolic disc turbine, etc.



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Impellers for highly viscous liquids

Helical ribbon impeller

- Having diameter almost equal to inside dia of tank
- Promotes liquid motion all the way to the tank wall with very viscous liquids

Anchor Impeller

- Creates no vertical motion
- Less effective than helical
- Promotes better heat transfer
- May have scrapers to remove liquid from tank wall

Helical ribbon impeller

http://www.fusionfluid.com/FusionFluidEquipmentLLC/html/impellers_helix.html

Anchor Impeller

https://www.spxflow.com/lightnin/products/r400-anchor-impeller/

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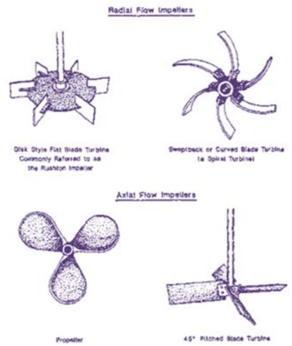
Various types of impellers



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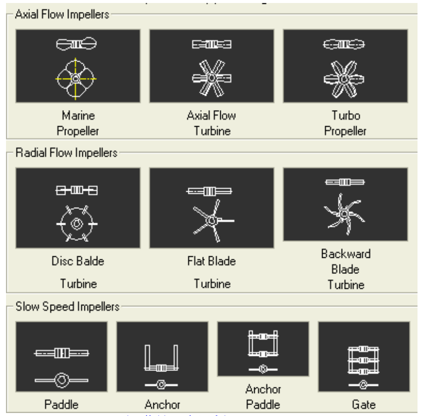

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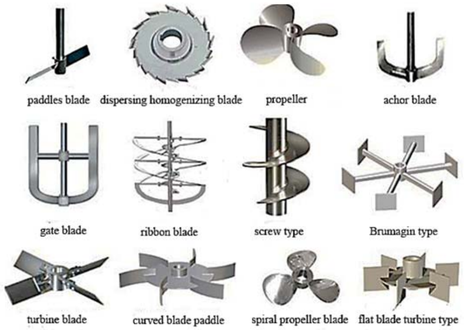

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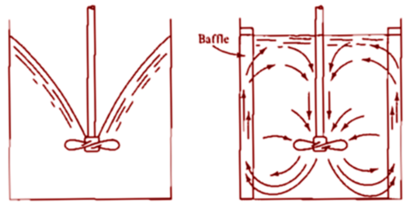
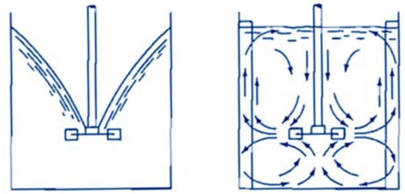
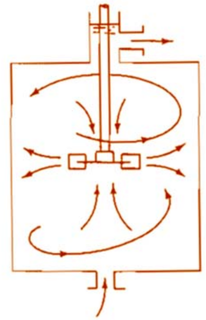
Typical flow patterns



Marine impeller with and without baffle (Partially filled vessel)



Disk flat blade turbines with and without baffle (Partially filled vessel)



Full filled vessel without Baffle

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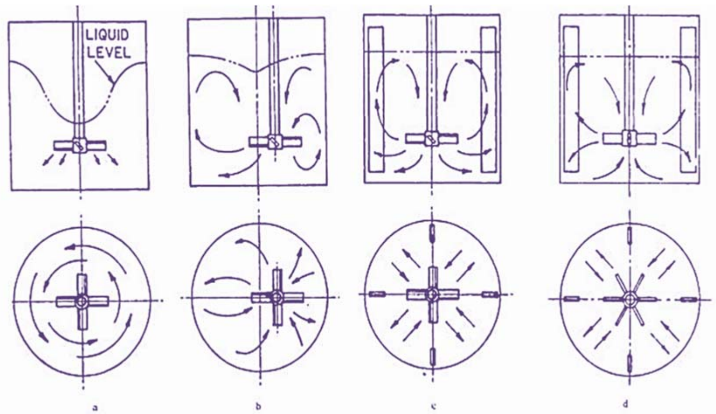

Figure Agitator flow patterns. (a) Axial or radial impellers without baffles produce vortexes. (b) Offcenter location reduces the vortex. (c) Axial impeller with baffles. (d) Radial impeller with baffles.

Power number

The **power number** N_p (also known as **Newton number**) is a commonly used **dimensionless number** relating the **resistance force** to the **inertia force**.

The power-number ($\boldsymbol{N_P}$) has different specifications according to the field of application. E.g., for stirrers the power number is defined as:

$$N_P = \frac{P}{n^3 D^5 \rho}$$

P: power
ρ: fluid density
n: rotational speed
D: diameter of stirrer

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References

ETH

Mass Transfer

Theories for Mass Transfer Coefficients

Lecture 9, 15.11.2017, Dr. K. Wegner

MASS TRANSFER OPERATIONS: ABSORPTION AND EXTRACTION

José Coca, Salvador Ordóñez, and Eva Díaz

Department of Chemical Engineering and Environmental Technology, University of Oviedo, Oviedo, SPAIN

7. Short introductions to: Mass transfer; Separation processes; Particulate technology & multi-phase flow

- Lecture notes/ppt of Dr. Yahya Banat (**ybanat@qu.edu.qa)**

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