Module 12: Agitation

Lecture 40: Equipment, flow patterns, power requirement

- Agitation of liquids
- Why agitation?
- Power requirement

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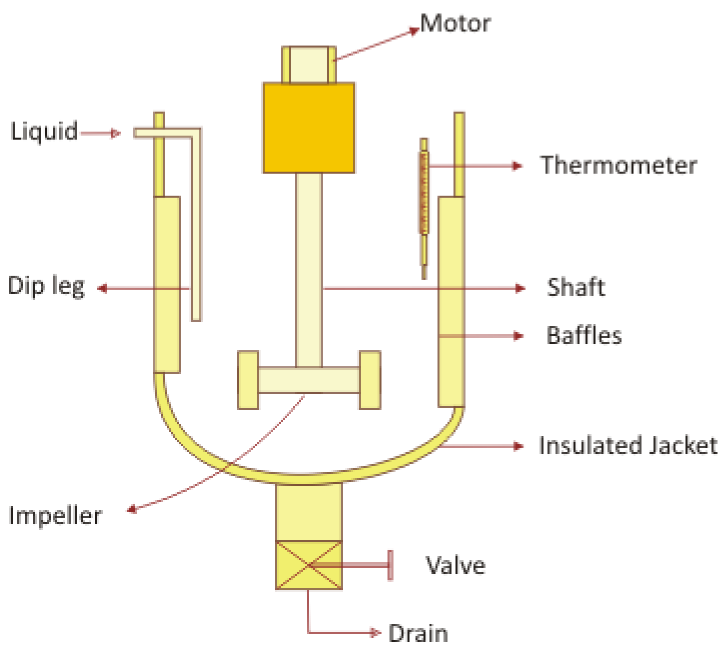
Agitation of liquids

- The unit operation is used to prepare liquid–mixture by bringing in contact two liquids in a mechanically agitated vessel or container.
- Agitation refers to the induced motion of liquid in some defined may, usually in circulatory pattern and is achieved by some mechanical device.

Why agitation?

- Dispenses a liquid which is immiscible with the other liquid by forming an emulsion or suspension of few drops.
- Suspends relatively lighter solid particles
- Promotes heat transfer between the liquid in the think or container and a coil or jacket surrounding the container
- Blends miscible liquids $(CH_2O \text{ and water})$



(Fig. 40a)

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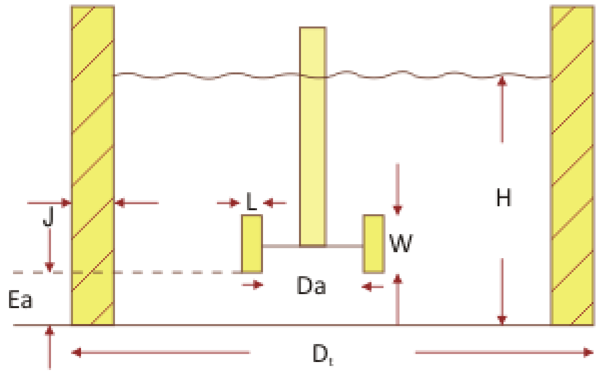
- The equipment consists of a tank with an insulated jacket, baffles, shaft with motor, impeller, and other accessories such as thermometer and dip- leg.

The role of baffles is to remove stratification in the radial direction and improve mixing,



(Fig. 40b)

- Typical configuration-dimensions are:
  $\#\text{of baffles} = 4, \#\text{ of impellers} = 1;$

$$\frac{Da}{Dt} = \frac{1}{3}; \quad \frac{H}{Dt} = 1, \quad \frac{J}{Dt} = \frac{1}{12}, \quad \frac{E_a}{Da} = 1, \quad \frac{W}{Da} = \frac{1}{5}, \quad \frac{1}{Da} = \frac{1}{4}$$

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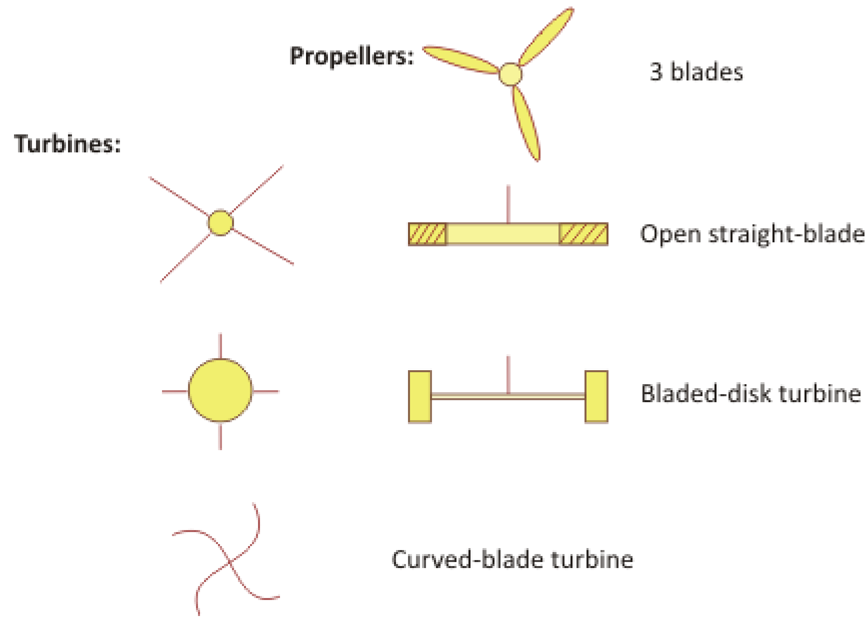
- Two types of impellers:
  - Radial flow impellers (flow is induced in radial or tangential directions)
  - Axial flow impellers (currents are parallel to the axis of impeller shaft)

- Two types of geometrical configurations:



(Fig. 40c)

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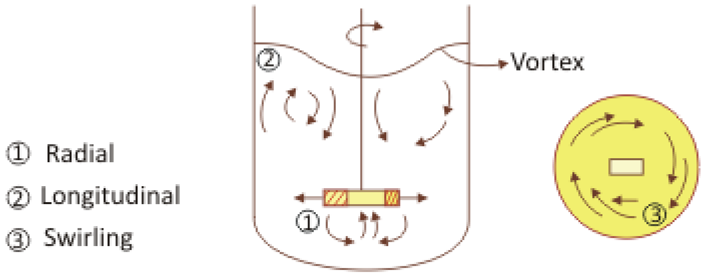
Flow patterns in agitated vessels

There are three principal currents in the vessel during agitation: (a) radial (perpendicular to the shaft) (b) tangential (tangential to the circular path) (c) longitudinal (parallel to the shaft)

1. Radia!
2. Longitudinal
3. Swirling



(Fig. 40d)

Notes:

- Tangential component induces vortex and swirling, which in turn create stratification responsible for non–uniform mixing. In such case fluid particles are followed by another fluid particle.
- At relatively higher rpm, the center of vortex may reach impeller and air may be sucked in. This may not be desirable.
- Swirling can be minimized by placing the shaft slightly away from the center of the vessel, or by putting baffles. In the latter–configuration, tangential streamlines will also be reduced.

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Power requirement

Dimensional analysis is used to determine the power requirement. Variables are

$(\mu_f, \rho_f, g, n, D_a, S_1, \quad S_2 \,..S_m)$

Relatively larger viscous fluid requires high power for mixing. Similarly, high density fluid–mixture also require large power for mixing:

$P' = P(\mu_f^2, \rho_g^3, g^4, n^5, D^6, S^7, S^8, S^9)$

From Buckingham $\mathrm{Pi} -$ theorem, no of independent dimensionless groups can be formed. For (6+m) variables, there will be (3 + m) groups:

a. Power number, $N_p = \frac{P}{n^3 D_a^5 \rho}$, $\eta = \text{rpm of impeller}$

b. Reynolds number, $N_{Re} = \frac{vD_a\rho}{\mu}$, where v is the tangential velocity of the tip of the impeller or $= \pi D_a n$

c. Froude number $F_r = \frac{n^2 D_a}{g} \left(\frac{\text{inertial force}}{\text{gravitational force}}\right)$

The other groups are $S_1 = \frac{H}{D_a}$, $S_2 = \frac{D_t}{D_a}, ..\text{etc}$

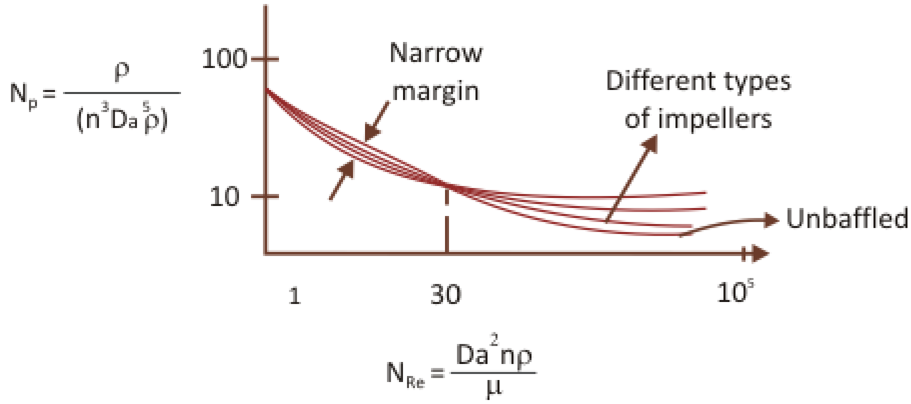
(Power number is analogous to friction factor and equals drag force on an unit area of impeller per KE of unit-fluid-volume)

Or,

$$N_p = \frac{P}{n^3\, Da^5\, \rho} = f\left(\frac{n\, Da^2\, \rho}{\mu}, \frac{n^2\, D_a}{g}, S_1, \quad S_2 \,.....S_n\right)$$

(Here, Reynolds number is based on peripheral speed and diameter of impeller)

Graphical results are available for different types of impellers to calculate power number:



(Fig. 40e)

(Slop is -1 on log–log plot for $R_e < 10$)

- As in the case of tubular flow flow, viscous effects are predominant and density of fluid is not important at low Reynolds number.

$$N_P . N_{RE} = \left(\frac{P}{n^2\ Da^3\ \mu}\right) \neq f(\rho)$$

$= \psi\ (S_1, s_2\ \ldots..S_n)$
$= K_L$(Tables are available to calculate K_L)

Or

$P = K_L\ (n^2 Da^3 \mu)$

- At high Reynolds number $> 10{,}000$, power number is independent of the Reynolds number and viscosity is not important. Flow is fully turbulent.

$N_P = K_T = \psi\ (S_1, s_2\ \ldots..S_n)\ \neq f(\mu)$

Or

$P = K_T\ (n^3 Da^5 \rho\ )$ (Tables are available to calculate P)

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