CHAPTER 9. AGITATION AND MIXING
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PRESENTATION OUTLINE
- Definitions
- Purposes of agitation
- Devices to produce agitation
- Power consumption of agitators
- Blending and Mixing
- Suspension of solid particles
- Dispersion Operations
- Agitator selection and Scale up

DEFINITIONS
- Agitation: It refers to the induced motion of a “homogenous” material in a specified way
- Mixing: It is the random distribution, into and through one another, of two or more initially separate phases

PURPOSES OF AGITATION
- Suspending solid particles
- Blending miscible liquids
- Dispersing a gas through the liquid
- Dispersing a second liquid to form an emulsion or suspension
- Promoting heat transfer
DEVICES TO PRODUCE AGITATION

IMPELLERS
- Propellers (high-speed, low viscosity)
- Turbines (Moderate viscosity)
- High-efficiency impellers

Source: McCabe et al. 2001

DESIGN OF TURBINES

\[ \frac{D_1}{D_2} = \frac{1}{3} S_1 \]
\[ \frac{E_1}{E_2} = \frac{1}{3} S_2 \]
\[ \frac{L}{D_2} = \frac{1}{12} S_3 \]
\[ \frac{W}{D_2} = \frac{1}{5} S_4 \]

Source: McCabe et al. 2001
POWER CONSUMPTION OF AGITATORS

It is a function of the volumetric flow rate and the kinetic energy

\[ q = \frac{1}{2} \beta \pi D_a^3 \tan \beta \pi D_a W \]

\[ q = \eta D_a \]

\[ N_q = \frac{q}{nD_a} \] (Flow number)

\[ E = \frac{1}{2} (\frac{q}{nD_a})^2 \]

\[ P = n E \]

\[ P = \rho N_q \left( \frac{\alpha n^2}{2} N_q \right) \]

\[ \frac{P}{\rho n D_a^3} = \frac{\alpha n^2}{2} N_q \]

\[ N_p = \frac{P}{\rho n D_a^3} \] (Power number)

**Values of** \( N_q \)

<table>
<thead>
<tr>
<th>Impeller</th>
<th>( N_q )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marine propellers (square pitch)</td>
<td>0.5</td>
</tr>
<tr>
<td>Four-blade 45° turbine (W/D = 10)</td>
<td>0.87</td>
</tr>
<tr>
<td>Disk turbine</td>
<td>1.3</td>
</tr>
<tr>
<td>He-3 high-efficiency impeller</td>
<td>0.47</td>
</tr>
</tbody>
</table>

\[ N_q = \varphi (Re, Fr, X_1, X_2, \ldots) \]

Source: McCabe et al. 2001
**BLENDING AND MIXING**

**TABLE 9.3**

<table>
<thead>
<tr>
<th>Type of impeller</th>
<th>$N_x$</th>
<th>$N_y$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propeller, time blades</td>
<td>41</td>
<td>5.32</td>
</tr>
<tr>
<td>Pitch 1°</td>
<td>46</td>
<td>5.01</td>
</tr>
<tr>
<td>4°</td>
<td>75</td>
<td>5.59</td>
</tr>
<tr>
<td>Mix-proof blades</td>
<td>20°, $S_x = 0.2$</td>
<td>10</td>
</tr>
<tr>
<td>Mix-proof blades</td>
<td>20°, $S_x = 0.3$</td>
<td>94</td>
</tr>
<tr>
<td>Mix-proof blades</td>
<td>40°, $S_x = 0.5$</td>
<td>85.5</td>
</tr>
<tr>
<td>HE-3 impeller</td>
<td>45</td>
<td>0.78</td>
</tr>
<tr>
<td>Helical blade</td>
<td>52</td>
<td>—</td>
</tr>
<tr>
<td>Turbo</td>
<td>598</td>
<td>0.15</td>
</tr>
</tbody>
</table>

**SOURCE:** McCabe et al. 2001

**FIGURE 9.15**

Power correlation for a six-blade turbine in pseudoplastic liquids.

**FIGURE 9.16**

Mixing times in agitated vessels. Dashed lines are for unbaffled tanks; solids lines are for baffled tanks.

**SOURCE:** McCabe et al. 2001

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SUSPENSION OF SOLID PARTICLES

\[ n \cdot D_e^{1.8} = \frac{S}{e} \cdot D_e^{0.8} \left( \frac{V_o}{D} \right)^{0.5} B_{1.6} \]

Shape factor S

<table>
<thead>
<tr>
<th>Impeller type</th>
<th>D/D_e</th>
<th>D/E_e</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td>Six-blade turbine</td>
<td>2</td>
<td>4</td>
<td>4.1</td>
</tr>
<tr>
<td>D/W=5</td>
<td>3</td>
<td>4</td>
<td>7.5</td>
</tr>
<tr>
<td>Np=6.2</td>
<td>4</td>
<td>4</td>
<td>11.5</td>
</tr>
<tr>
<td>Two-blade paddle</td>
<td>2</td>
<td>4</td>
<td>4.8</td>
</tr>
<tr>
<td>D/W=3</td>
<td>3</td>
<td>4</td>
<td>8.5</td>
</tr>
<tr>
<td>Np=2.5</td>
<td>4</td>
<td>4</td>
<td>12.5</td>
</tr>
<tr>
<td>Three-blade</td>
<td>3</td>
<td>4</td>
<td>6.5</td>
</tr>
<tr>
<td>propeller</td>
<td>4</td>
<td>4</td>
<td>8.5</td>
</tr>
<tr>
<td>Np=0.5</td>
<td>4</td>
<td>2.5</td>
<td>9.5</td>
</tr>
</tbody>
</table>

Source: McCabe et al. 2001
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AGITATOR SELECTION AND SCALE UP

AGITATOR SELECTION

- Depends on the viscosity of the liquid
- For specific time of mixing, the best mixer is the one that mixes in the required time with the smallest amount of power

SCALE UP

- Maintaining constant power per unit volume and geometric similarity

\[
\frac{n_2}{n_1} = \left( \frac{D_2}{D_1} \right)^{1.7}
\]