Power curves

A power curve is a plot of the power function Ø or the power number P_o against the Reynolds number for mixing($Re)_m$ on log-log coordinates.

Each geometrical configuration has its own power curve and since the plot involves dimensionless groups it is independent of tank size. Thus a power curve used to correlate power data in a 1 m^3 tank system is also valid for a $1000m^3$ tank system provided that both tank systems have the same geometrical configuration .

Figure (2) shows the power curve for the standard tank configuration geometrically illustrated in Figure (1) .

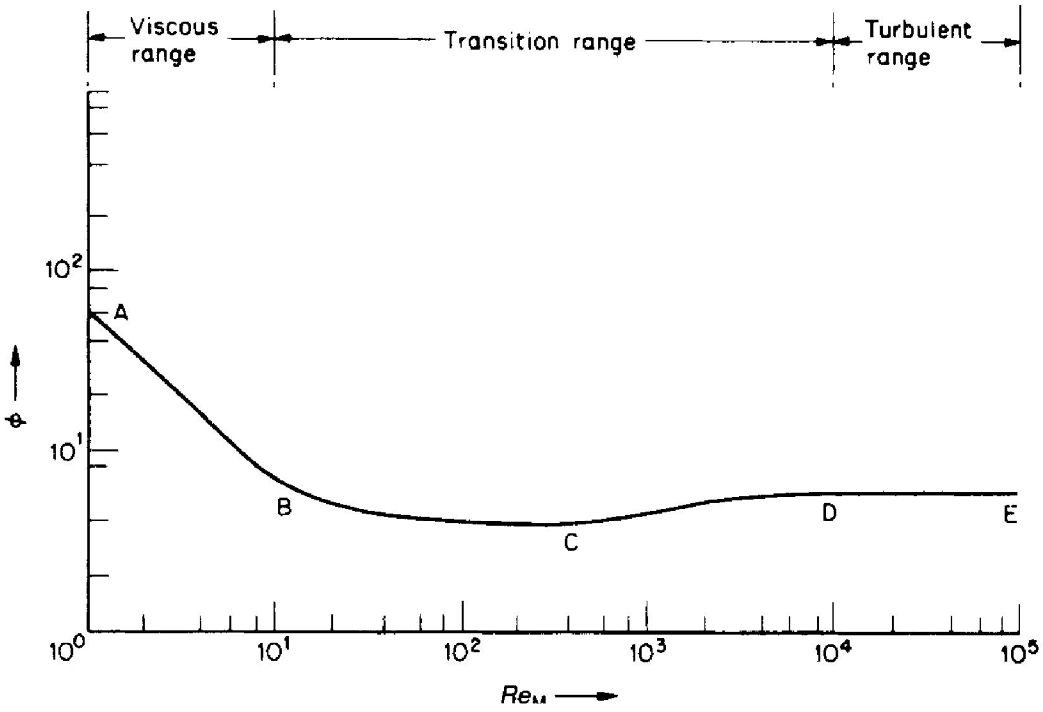

Figure 5.8 Power curve for the standard tank configuration

Since this is a baffled non- vortexing system, equation 8 applies.

$$\log P_0 = \log C + X\log(Re)_m^x$$

The power curve for the standard tank configuration is linear in the laminar flow region (AB) with a slope of (-1) . Thus in this region for $(Re)_m < 10$, equation (8) can be written as :

$$\log P_0 = \log C - \log(Re)_m \quad \text{-------------9}$$

Which can be rearranged to :

$$P_A = C\mu N^2 D_A^3 \quad \text{-------------10}$$

where C = 71.0 for the standard tank configuration. Thus for laminar flow, power is directly proportional to dynamic viscosity for a fixed agitator speed .

For the transition flow region **BCD** which extends up to $\mathbf{(Re)_m}$ = 10000, the parameters ***C*** and **x** in equation (8) vary continuously.
In the fully turbulent flow region DE, the curve becomes horizontal and the power function **Ø** is independent of the Reynolds number for mixing $\mathbf{(Re)_m}$ **.** For the region $\boldsymbol{Re_m}$ > **10000** , ***Ø*** $\boldsymbol{= P_o = 6.3}$ **.**
At point C on the power curve for the standard tank configuration given in Figure (2) , enough energy is being transferred to the liquid for vortexing to start. However the baffles in the tank prevent this. If the baffles were not present vortexing would develop and the power curve would be as shown in Figure (3) .

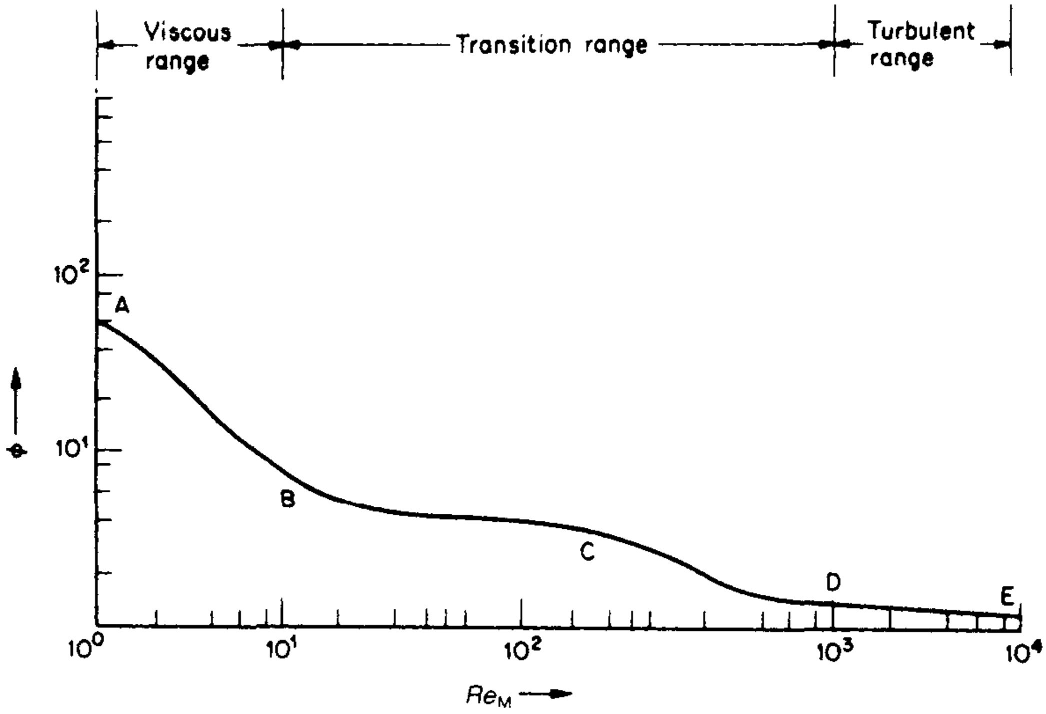

Fig.(3) Power curve for the standard tank configuration without baffles

For the unbaffled system

The power curve for the baffled sys. Is identical with the power curve for the un baffled sys. up to point ***C*** where Re_m = 300. As the Reynolds number for mixing Re_m increases beyond point ***C*** in the unbaffled system, vortexing increases and the power falls sharply. Equation 5 can be written in the form

$$\log P = \log C + X \log(Re)_m + y \log(Fr)_m$$

For the unbaffled system, $\emptyset = P_o$ at $Re_m \leq 300$ and $\emptyset = P_o / (Fr)^{y}_{m}$ at $(Re)_m > 300$, to find of const. y

i) A plot of P_o against Re_m on log-log coordinates for the unbaffled system gives a family of curves at ***Re, > 300.*** Each curve has a constant Froude number for mixing Fr_m.

ii) A plot of P_o against Fr_m on log-log coordinates is a straight line of slope ***y*** at a constant Reynolds number for mixing Re_m . A number of lines can be plotted for different values of Re_m.

iii) A plot of y against log Re_m is also a straight line. If the slope of the line is (- l/β) and the intercept at Re_m = 1 is **Re,** > 300. (α/β) then

$$y = \frac{\propto - \log Re_m}{\beta}$$

Sub. In $\emptyset = \frac{P}{(Fr)_m^y} = C(Re)_m^x$ to given

$$\emptyset = \frac{\frac{P}{\alpha - \log Re/\beta}}{Fr_m}$$

For a 6-blade flat blade turbine agitator 0.1m index α=1 and β =40

- For baffled sys. $P_A = P_0 \rho N^3 D_A^5$
- For unbaffled sys. $P_A = \emptyset \rho N^3 D_A^5 (Fr)_m^y$

Ex 1 : Calculate the theoretical power for a six-blade flat blade turbine agitator with diameter D_A = **3** m running at a speed of N = 0.2 rev/s in a tank system conforming to the standard tank configuration illustrated in Figure 5.5. The liquid in the tank has a dynamic viscosity μ= 1.0 Pa s and a density of ρ = 1000 kg/m^3 .

Calculations

The Reynolds number for mixing is

$$(Re)_m = \frac{\rho N D_A^2}{\mu}$$

Substituting the given values

$$(Re)_m = \frac{(1000\ kg/m^3).(0.2\ rev/s).(3m)^2}{1.0\ Pa\ s}$$

$$(Re)_m = 1800$$

From the graph of $\emptyset$ against Re_m in Figure ***5.8***

$\emptyset = P_o = 4.5$

The theoretical power for mixing is

$$P_A = P_0 \rho N^3 D_A^5$$

$$P_A = (4.5)(1000\, kg/m^3)(0.008\, rev^3/s^3)(243 m^3)$$
$$P_A = 8748\, W$$

For non-Newtonian liquid

Magnusson calculated the apparent viscosities of non-Newtonian liquids $\mu_a = k(du/dy)^{n-1}$ in agitated tanks from the appropriate power curve for Newtonian liquids . Metzner and Oflo used this procedure to obtained the dimensionless proportionality constant k in equ. $\dot{\gamma}_{av}.KN$ [the mean shear rate produced by an agitator in a mixing tank $(\dot{\gamma}_{av})$ is proportional to the rotational speed of the agitator , N i.e. $\dot{\gamma}_{av} = KN$] and a non – Newtonian power curve for a particular system geometry .

$$(Re)_m = \frac{\rho N D^2}{\mu_a}$$
$$(Re)_m = \frac{\rho N D^2}{k(du/dy)^{n-1}{}_{av}}$$

But

$$(du/dy)_{av} = KN$$

Then

$$(Re)_m = \frac{\rho N D^2}{k(KN)^{n-1}}$$

$$(Re)_m = \frac{\rho N^{2-n} D^2}{k\, K^{n-1}}$$