CENTRIFUGAL SEPARATIONS

The separation by sedimentation of two immiscible liquids, or of a liquid and a solid, depends on the effects of gravity on the components . Sometimes this separation may be very slow because the specific gravities of the components may not be very different, or because of forces holding the components in association. Also, under circumstances when sedimentation does occur there may not be a clear demarcation between the components but rather a merging of the layers . Centrifuges are classified according to the mechanism used for solids separation:

(a) Sedimentation centrifuges: in which the separation is dependent on a difference in density between the solid and liquid phases (solid heavier) .

(b) Filtration centrifuges: which separate the phases by filtration. The walls of the centrifuge basket are porous , and the liquid filters through the deposited cake of solids and is removed . The choice between a sedimentation or filtration centrifuge for a particular application will depend on ;

- the nature of the feed
- the product requirements .

THEORY OF CENTRIFUGAL

The centrifugal forces imposed are so much greater than gravity, the effects of gravity force can usually be neglected in the analysis of the separation . The centrifugal force depends upon;

1. A radius of rotation
2. speed of rotation
3. the mass of the particle.

The centrifugal force F_c on a particle that is constrained to rotate in a circular path is given by

$F_c = m\, r\, \omega^2$ and $\omega = v/r$

$$F_c = (mv^2)/r \qquad (1)$$

where :
r : is the radius of the path (radius of cyclone) ,
m : is the mass of the particle ,
ω (Omega) : is the angular velocity of the particle (rad/s).
v : is the tangential velocity of the particle
Rotational speeds (N) are normally expressed in revolutions per minute, as it has to be in second , divide by 60)
$\omega = 2\pi N/60$

$$F_c = mr(2\pi N/60)^2 = 0.011mrN^2 \qquad (2)$$

If this is compared with the force of gravity (F_g= mg) on the particle, it can be seen that the centrifugal acceleration, equal to $g = 0.011\ rN^2$
The steady-state velocity of particles moving in a streamline flow under the action of an accelerating force is , from Stokes' Law

$$V_m = \frac{D_p{}^2 g(\rho_p - \rho_c)}{18\mu}$$

If g streamline flow occurs in a centrifuge we can write ,

$$V_m = \frac{D_p{}^2\, r(2\pi N/60)^2(\rho_p - \rho_c)}{18\mu}$$

$$V_m = \frac{D_p{}^2\, r\, N^2(\rho_p - \rho_c)}{1640\ \mu} \qquad (3)$$

For example, if two liquids, one of which is twice as dense as the other, are placed in a bowl and the bowl is rotated about a vertical axis at high speed , the centrifugal force per unit volume will be twice as great for the heavier liquid as for the lighter. The heavy liquid will therefore move to occupy the annulus at the periphery of the bowl and it will displace the lighter liquid towards the centre .

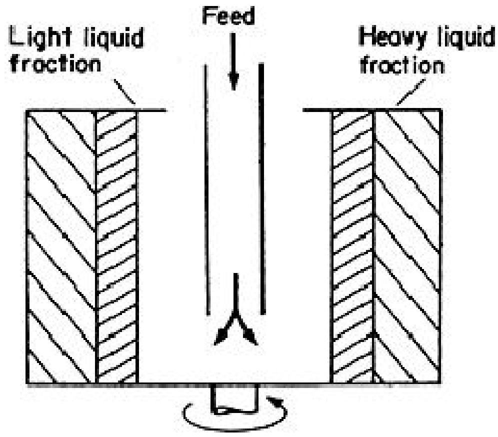

Fig. *Liquid separation in a centrifuge*

EX :

A dispersion of oil in water is to be separated using a centrifuge. Assume that the oil is dispersed in the form of spherical globules 51 μ m diameter and that its density is 894 kg/m^3. If the centrifuge rotates at 1500 rev/min and the effective radius at which the separation occurs is 3.8 cm ,

(a) calculate the velocity of the oil through the water .

(b) the centrifugal acceleration . Take the density of water to be 1000 kg/m^3 and its viscosity to be 0.7 x 10^{-3} N s/m^2 .

Solution

(a) the rate of settling under gravity

$$V_m = \frac{D_p{}^2\, r\, N^2(\rho_p - \rho_c)}{1640\, \mu}$$

$V_m = (5.1x10^{-5})^2\ x1500^2\ x\ 0.038(1000\text{-}894)/(1640x0.7x10^{-3})$

$V_m = 0.02\ m/s$

Checking that it is reasonable to assume Stokes' Law

Re = (Dvρ/μ)= (5.1 x10^{-5} x 0.02 x 1000)/(7.0 x 10^{-4}) = 1.5

so that the flow is streamline and it should obey Stokes' Law.

(b)

g = 0.011 rN^2= 0.011 x 0.038 x 1500^2

$g = 940.6\ m^2/s$