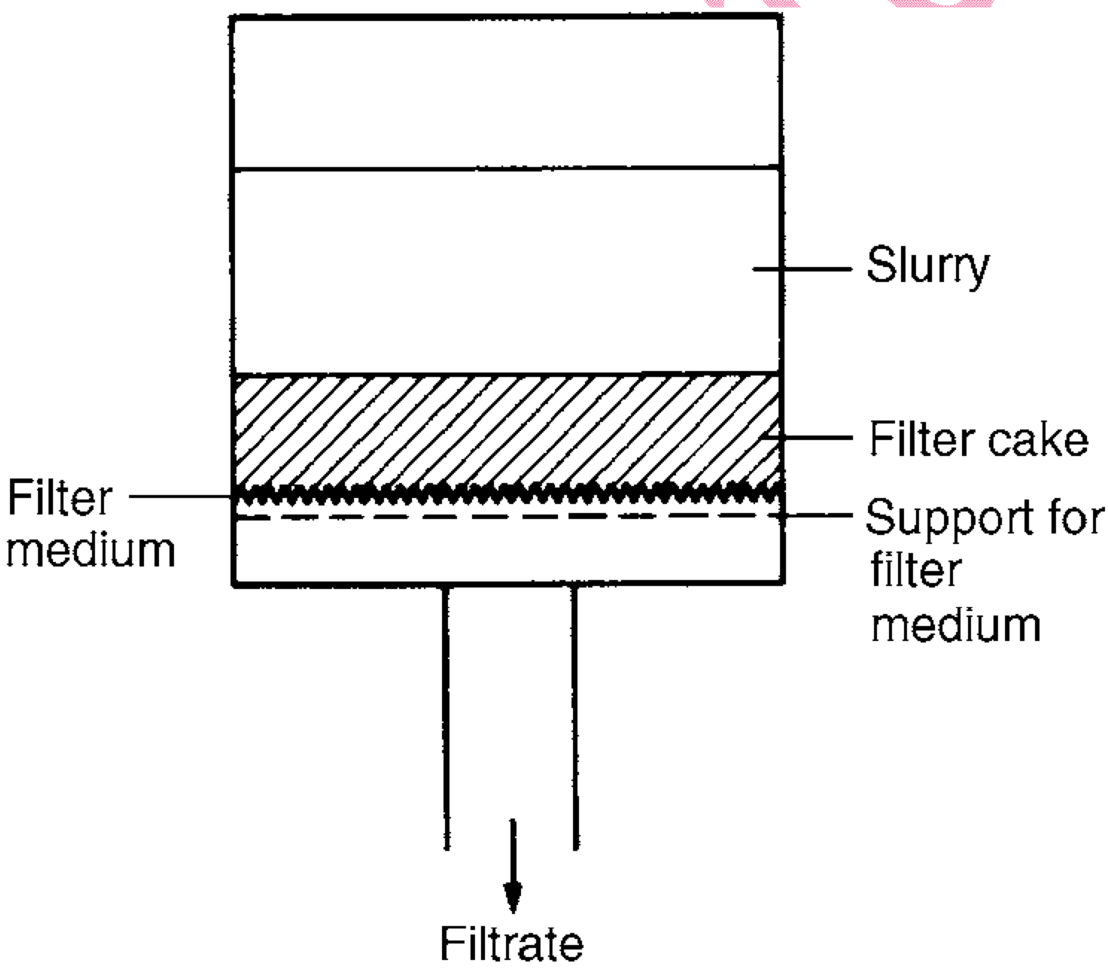
Filtration

Introduction

The separation of solids from a suspension in a liquid by means of a porous medium or screen which retains the solids and allows the liquid to pass is termed filtration.

In general, the pores of the medium are larger than the particles which are to be removed, and the filter works efficiently only after an initial deposit has been trapped in the medium .



The most important factors on which the rate of filtration then depends will be:

(a) The drop in pressure from the feed to the far side of the filter medium.

(b) The area of the filtering surface.

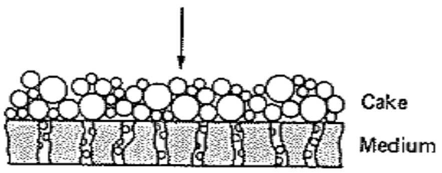
(c) The viscosity of the filtrate.

(d) The resistance of the filter cake.

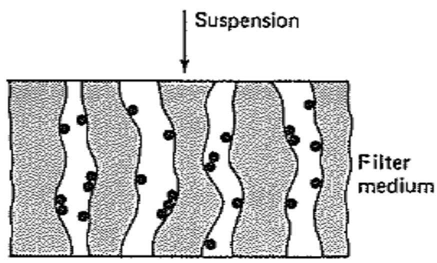
(e) The resistance of the filter medium and initial layers of cake .

Type of Filtration

Cake Filtration **Deep Bed Filtration**



(a)



(b)

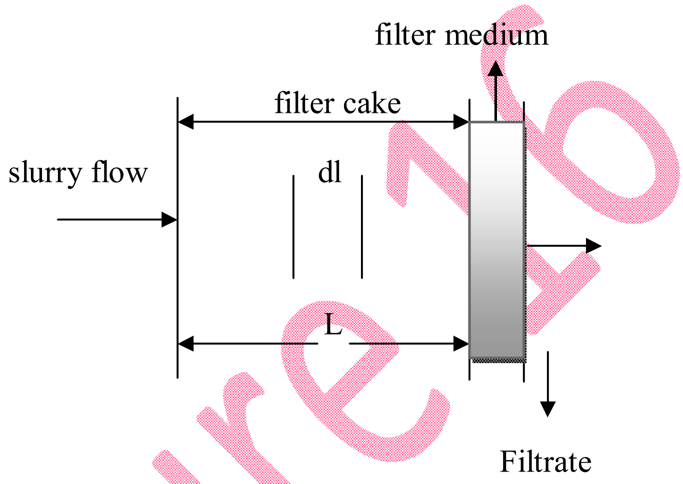
1- Cake filtration

Where the proportion of solids in suspension is large and most of the particles are collected in the filter cake which can subsequently be detached from the medium .

2- Deep bed filtration

Where the proportion of solids is very small , as for example in air or water filtration , the particles will often be considerably smaller than the pores of the filter medium and will penetrate a considerable depth be for being captured .

Theory of Filtration



Because the particles forming the cake are small and the flow through bed is slow , streamline conditions are almost in variably obtained , and therefore at any instant may be represented as :

$$U = \frac{1}{A} . \frac{dV}{dt} = \frac{e^3}{5(1-e)^2 S^2} . \frac{\Delta P}{\mu l}$$ ----------------(1) Kozeny eq.

Where

V : is the volume of filtrate which has passed in time t (m^3) .

A : is the total cross-sectional area of the filter cake(m^2) .

U : is the superficial velocity of the filtrate (m/s) .

L : is the cake thickness (m)

S : is the specific surface of the particles (m^{-1})

e : is the voidage .

μ : is the viscosity of the filtrate (kg/m.s)

ΔP :is the applied pressure difference (N/m^2) .

Filter cakes may be divided into two classes—incompressible cakes and compressible cakes .

For incompressible cakes (e) in equation (1) may be taken as constant and the quantity ($e^3/[5(1-e)^2S^2]$) is then a property of the particles forming the cake and should be constant for a given material therefore

$$\frac{1}{A}.\frac{dV}{dt}=\frac{\Delta P}{r\mu l}$$ -----------(2) Basic filtration eq

.

Where:

r = specific resistance = ($5(1-e)^2S^2 / e^3$)

Relation between thickness of cake and volume of filtrate

In equation (2), the variables l and V are connected, and the relation between them may be obtained by making a material balance between the solids in both the slurry and the cake as follows.

Mass of solids in filter cake = $(1-e)A\,l\,\rho_s$.

where ρ_s is the density of the solids

Mass of liquid retained in the filter cake = $e\,A\,l\,\rho$.

where ρ is the density of the filtrate.

Let X is the mass fraction of solids in the original suspension then:

$$X=\frac{mass\ of\ solid}{mass\ of\ solid+mass\ of\ liq.}$$

And X = mass ratio of solid to liq.

$$X = \frac{mass\ of\ solid\ (\ in\ filter\ cake\ )}{mass\ of\ filtrate + mass\ of\ liq.\ retained\ in\ cake}$$

$$= \frac{(1-e)Al\rho_s}{\rho V + eAl\rho}$$

Also

$$X = \frac{X}{1-X}$$

Then

$$\frac{(1-e)Al\rho_s}{\rho V + eAl\rho} = \frac{X}{1-X} \rightarrow (1-e)(1-X)\rho_s = X\rho(V + Ale)$$

$$\therefore L = \frac{\rho V X}{[A(1-X)(1-e)\rho_s - \rho X e]}$$ (Thickness of cake)

$$V = \frac{AL[(1-X)(1-e)\rho_s - \rho X e]}{\rho\ X}$$ (vol. of filtrate)

If v is the volume of cake deposited by unit volume of filtrate then :

$$v = \frac{AL}{V} \quad or \quad L = \frac{vV}{A}$$

Sub.s in eq. (L) above

$$v = \frac{\rho X}{(1-X)(1-e)\rho_s - \rho X e}$$

Sub. for (L) in eq. (2)

$$\frac{1}{A} \cdot \frac{dV}{dt} = \frac{A}{vV} \cdot \frac{\Delta P}{r\mu} \quad or \quad \frac{dV}{dt} = \frac{A^2(\Delta p)}{r\mu v V} \quad or \quad \frac{dL}{dt} = \frac{\Delta p}{r\mu v L}$$