Capture of Small Particles in Magnetic Separators

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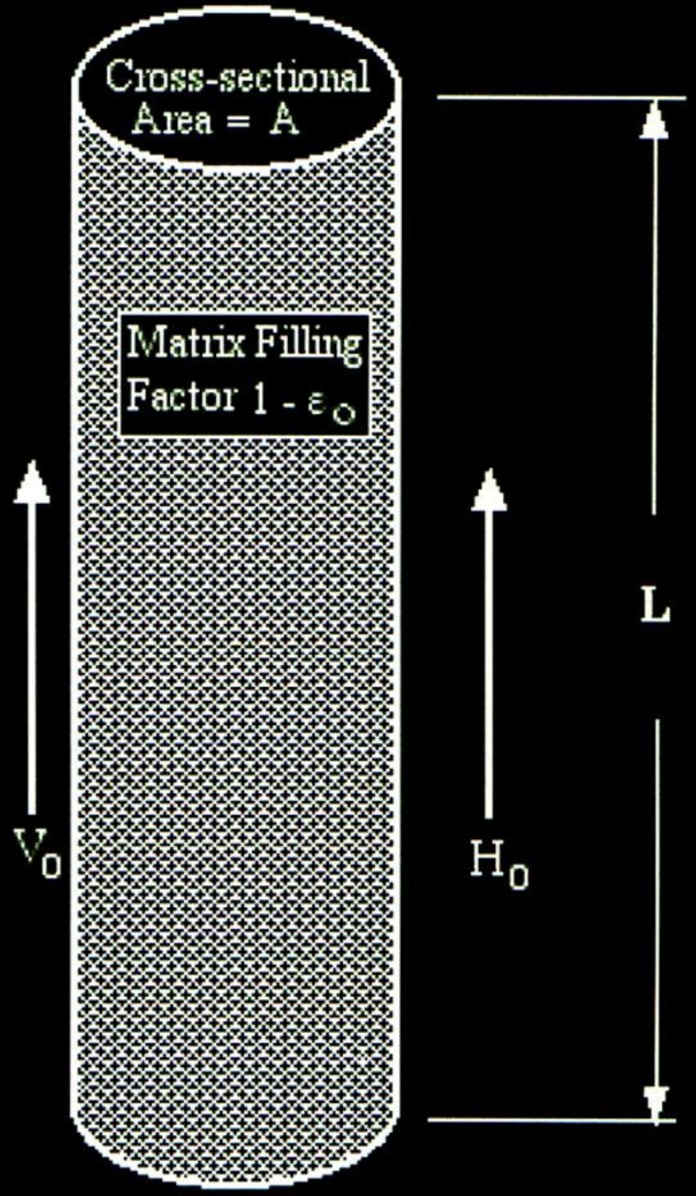
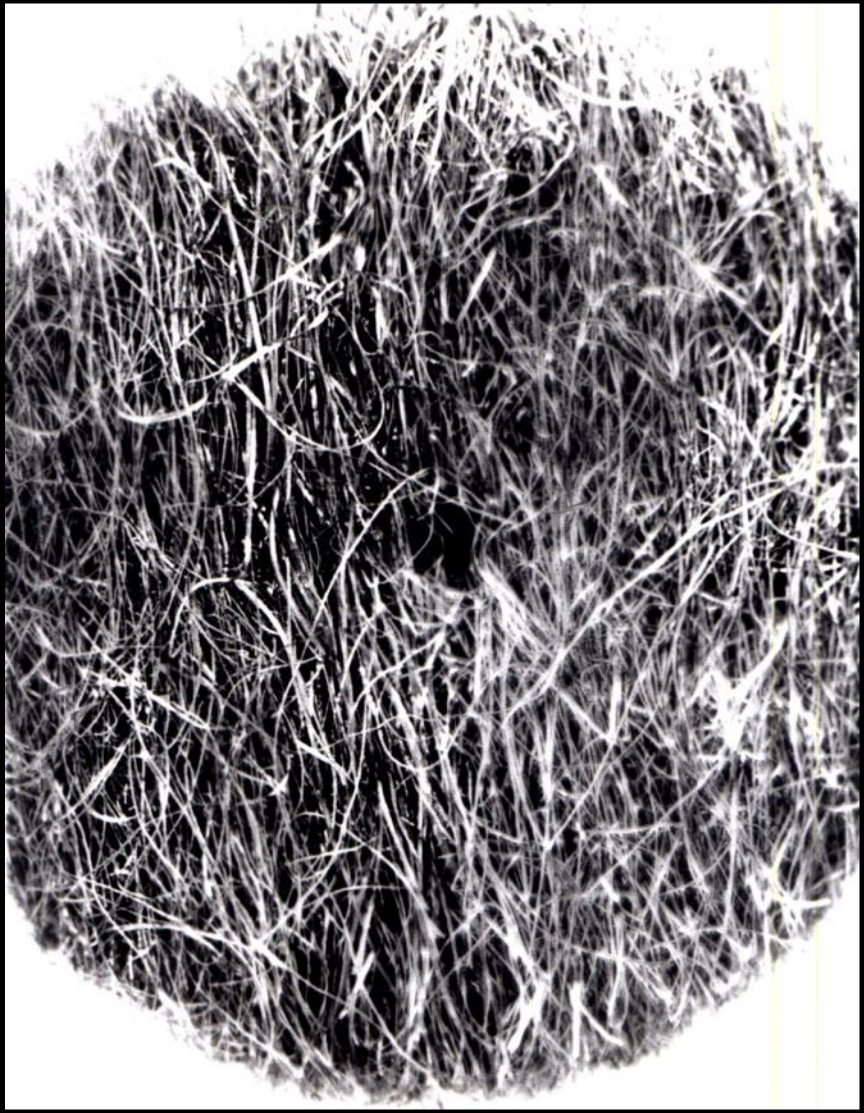
Canister with Magnetic Matrix



Ferromagnetic 430 Stainless Steel 75 micron Diameter



High gradient magnetic separator

High gradient magnetic separator.

(A) Clean filter

$R - dR$

$B_0 = \mu_0 H_0$

V_0

Vol. occupied by wire is $(1 - \epsilon_0)$

$R(x)$ no. of particles / m^3 of suspension at position x

N is no. of captured particles

dx

No. of particles captured in dx is $2a\, R_c\, X$ (active length of filter element in dx)

$$|dN| = |dR| = (2a\, R_c)\left(\frac{2}{3}\,\frac{(1-\epsilon_0)\,dx}{\pi a^2}\right) = \frac{4}{3}\frac{(1-\epsilon_0)}{\pi a} R_c R$$

For a clean system for a filter of length L

$$\boxed{\begin{aligned} R(L) &= R(0)\exp\left(-4(1-\epsilon_0)R_c L / 3\pi a\right) \\ &= R(0)\exp\left(-L/L_0\right) \end{aligned}}$$

$$\boxed{L_0 = 3\pi a / 4(1-\epsilon_0)R_c} \quad \text{characteristic length of filter.}$$

Ref. J.H.P. WATSON 'MAGNETIC Filtration' J. Appl. Phys. 44 No9, 4209-13 (1973)

Assumptions

(1) Overlap capture areas in dx are small

$(1-\epsilon_0)R_c \ll 1$

$(1-\epsilon_0) \sim .05$

(2) The particle interacts with one wire at a time.

Depends on V_m/V_0 and $(1-\epsilon_0)$. If $1-\epsilon_0 = .05$ then at $V_m/V_0 = 10$, the approx. is good.

(3) Any element dx contains $2/3 \perp H_0$ and $1/3 \parallel H_0$

Experimental results for clean filter

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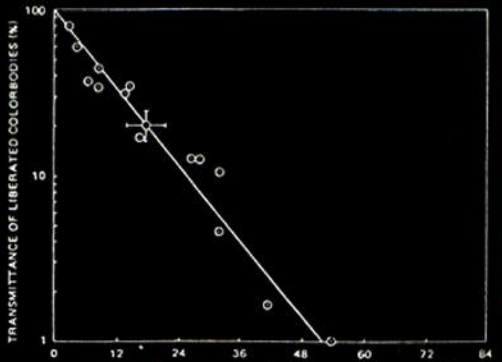


$H_o T$ (arbitrary units).

Note

In these experiments only V_o was varied and not L.

$R_c = \frac{V_m}{2V_o}$

$\frac{L}{L_o} \sim H_o T$

$\boxed{T = \frac{\epsilon_o L}{V_o}}$ where L is filter length.

$T = \epsilon_o \frac{L}{V_o}$

If $R_c \propto V_m / V_o$ this fits the theoretical prediction.

Ref R.R. Oder & CR Price, AIP Conf. Proc. No 29 641-643. Am. Inst of Physics (1975).

Partially full filter

Partially full filter J.H.P. Watson IEEE Trans. Magn. MAG14, 240-5 (1978)

For the filter between $x = 0$ and $x = L$ using x as the position through the filter it is useful to introduce τ the filter time

$$\boxed{\tau = t - \epsilon_0 x / V_0}$$

Mass and fluid balance give

$$\partial N/\partial t + \epsilon_0 \, \partial R/\partial t + V_0 \, \partial R/\partial x = 0$$

which becomes

$$\boxed{\begin{aligned} (\partial N/\partial \tau)_x + V_0 (\partial R/\partial x)_\tau &= 0 \\ (\partial N/\partial \tau)_x &= 4(1-\epsilon_0) R_c V_0 R / 3\pi a \end{aligned}}$$

Take $\boxed{R_c = R_{co}.\, G(f/f_{max}) = R_{co}\, G(N/N_T)}$

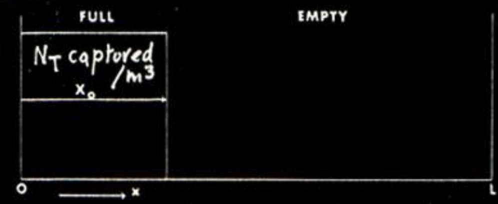
where $N_T \equiv f_{max}$. $\boxed{G = (1 - N/N_T)^{\gamma}}$

Riley and Watson (Digests of Intermag Conf. 1975 IEEE Publ. No 75 CHO 932-4 MAG) used $G = 1 - (N/N_T)^{0.12}$ to fit Fe_2O_3 monodisperse particles b between $1 - 1.25\mu m$. and obtained good fit.

Strong-coupling model

Strong-coupling model.

Assume that $L \gg L_0$



Position of captured material in separator. It is assumed that the separator is full up to a distance x_0 from the front where x_0 is determined by assuming that all the particles are captured. The small number of particles escaping is determined by the probability of escape through a thickness of matrix $L - x_0$.

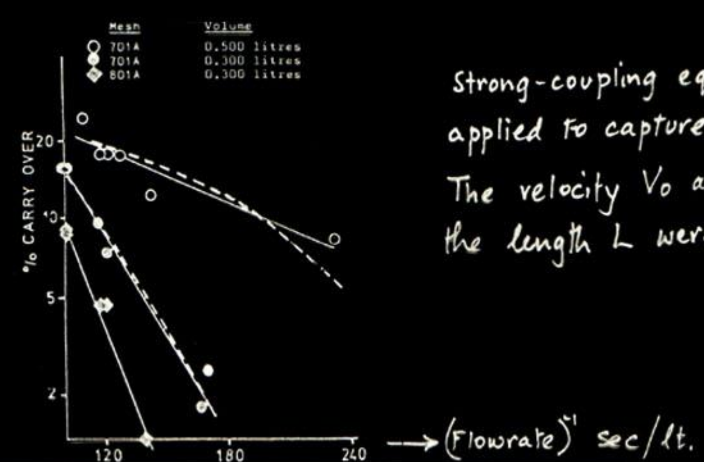
$$\boxed{\frac{R(L,\tau)}{R(0)} = \exp\left(-\frac{(L-X_0)}{L_0}\right)}$$

The effective length of the filter is $L - X_0$ and X_0 increases with time.

$$\boxed{\ln\left(R(L,\tau)/R(0)\right) = -L/L_0 + R(0)V_0\tau/N_T L_0}$$

with $\tau = nT$ where $T = \epsilon_0 L/V_0$ residence time

$$\boxed{\ln\left(R(L,\tau)/R(0)\right) = -\left(V_0/L_0 H_0 \epsilon_0\right)\left(1 - \epsilon_0 n R_0/N_T\right) H_0 T}$$

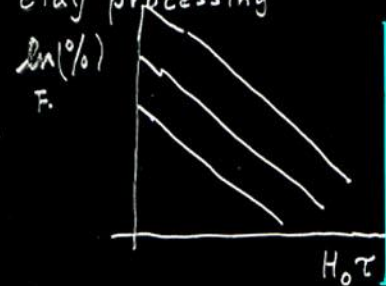


Strong-coupling equations applied to capture results. The velocity V_0 and not the length L were varied.

Magnetic retention of Poly-disperse Particle Systems

Magnetic retention of Poly-disperse Particle Systems

1. Most theories of HGMS are for mono-disperse (mono size) particles
2. In applying these to real systems of polydisperse particles it is assumed that each size can be treated separately and added together at the end — THIS IS WRONG.
3. In clay processing



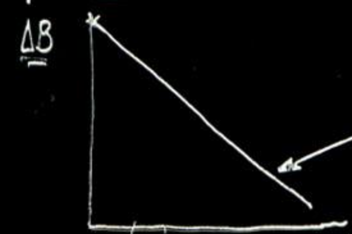
$$\ln\left(\frac{N_{out}}{N_{in}}\right) = -\frac{4 F R_c L}{3\pi a}$$

$$R_c = \frac{V_m}{2V_o} \underset{L}{\propto} \frac{H_o}{V_o}$$

$$\tau = \frac{L}{V_o}$$

where H_o and V_o have been varied

$\tau = L/V$ If L is varied it does not fit the formula.



depends only of H_o/V_o not on L

4. In the separation of chromium metal

$$\boxed{\ln\left(N_{out}/N_{in}\right) = -\frac{L}{L_o} + \frac{N_{in} V_o t}{N_T L_o}}$$

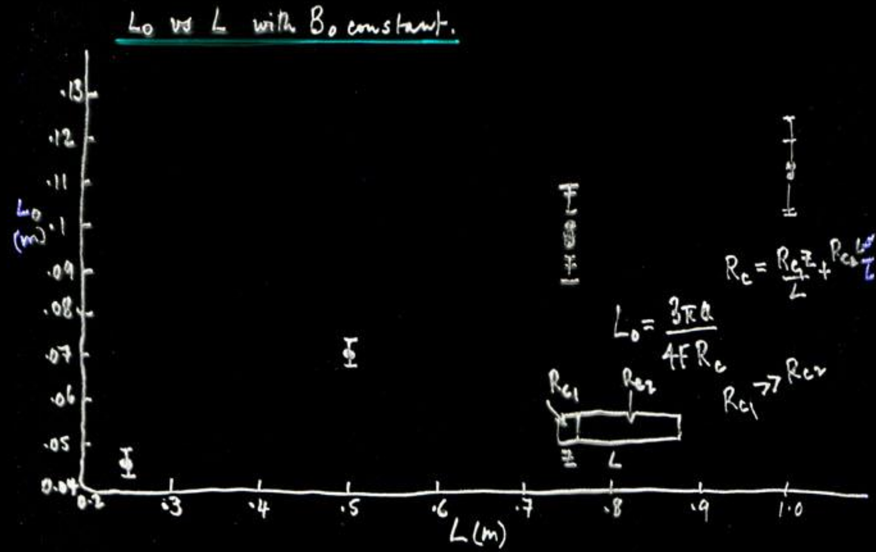
$N_V = 5\cdot10^{-4}$
$\bar{b} \sim 5\,\mu m$.

$$L_o = \frac{3\pi a}{4 R_c F}$$

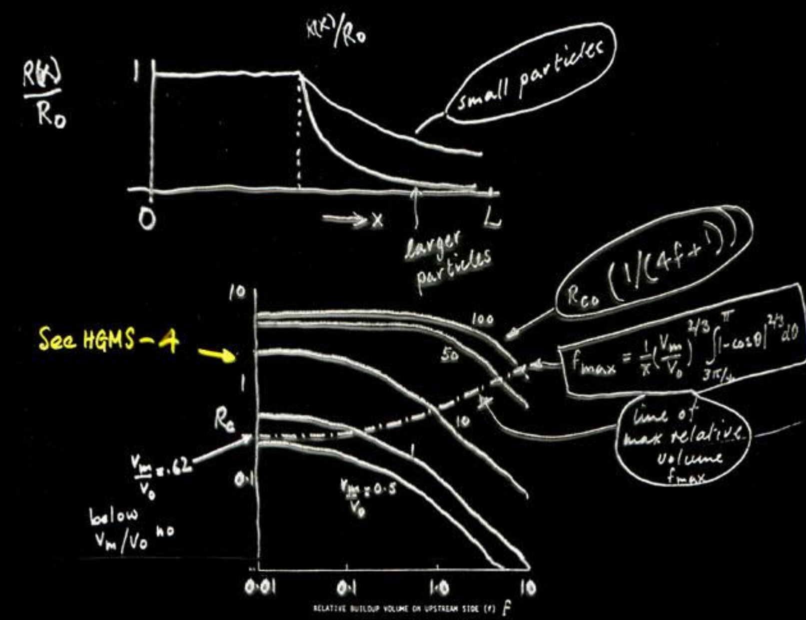
L_o should not depend on L

This equation can be applied to each particle fraction.
but instead of N_{in} used total number of N particles of all

Polydisperse Particle Systems



This means that the front of filter is much more effective than the extra length. (This leads to the advantage of the radial feed system.)



Polydisperse Particle Systems

Volume between particles is $8b^3 - \frac{4}{3}\pi b^3$ but only half this is accessible. $Vol = 2b^3(2 - \pi/3)$.

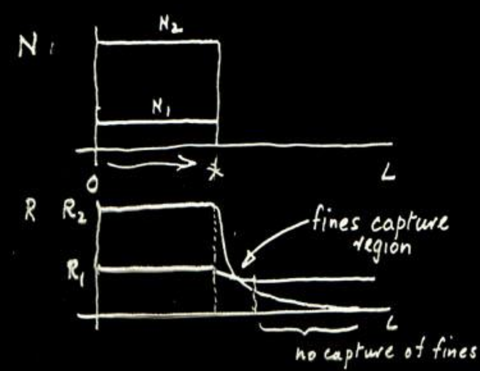
The maximum deposition rate of the fines must be

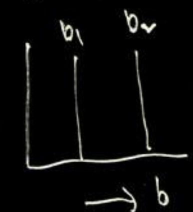
$$\frac{dN_1}{dt} \leqslant \left(\frac{6-\pi}{2\pi f_1}\right)\left(\frac{b_2^3}{b_1^3}\right)\left(\frac{dN_2}{dt}\right)$$

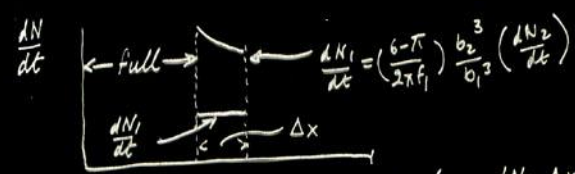
If dN_1/dt satisfies this capture is determined by R_c from graph. If inequality is not satisfied then $R_c = 0$ if $\frac{V_m}{V_0} < .62$ otherwise it depends on f.

Consider the strong-coupling limit take a bimodal system

R_{c_1} normally zero as $V_m/V_0 < .62$ $\quad R_{c_2} > 0 \quad \frac{V_m}{V_0} \gg .62$







$$R_{out} = -R_1 \frac{dN_1}{dt}\frac{\Delta x}{V_0} + R_1 = R_1\left(1 - \frac{dN_1}{dt}\cdot\frac{\Delta x}{V_0}\right)$$

Rout is independent of length.

Rout(H) can be greater as the field is lowered.