Scale up calculation in Filtration Process

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Abstract : Filtration processes play a pivotal role in various industries ranging from pharmaceuticals to wastewater treatment, where the efficient separation of solids from liquids is essential. As industries strive for enhanced productivity, the scale-up of filtration processes from laboratory to industrial levels becomes imperative. The paper begins by elucidating the fundamental principles of filtration and the parameters influencing its efficiency and pressure differentials It then delves into the intricacies of scale-up calculations, which involve extrapolating laboratory-scale data to predict the performance of larger filtration systems accurately. Case studies from diverse industrial sectors are presented to illustrate the application of scale-up calculations in real-world scenarios, showcasing successful implementations and lessons learned.

Index Terms - Pressure Filter, Cake Filtration, Scale up, Specific Cake Resistance.

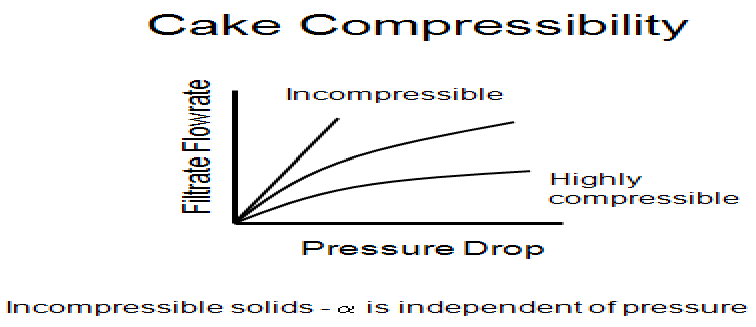
1. Introduction:[1][2]

Pressure filters, with exception of rotary drum pressure filter, are semi continuous type machines that enter a wash and cake discharge mode at the end of the filtration cycle. The filtration cycle may extend from 5-10 mins on cake filtration applications and up to 8 or even more hours for the polishing of liquids. Since operation is in batches, that are usually fed from and discharged to a continuous process, a surge tank is required upstream the filter and batch collection of cake downstream the filter. The collection of filtrate depends on operating mode of the filter which can be constant flow rate, constant pressure or both pressure rising and flow rate reducing as for a centrifugal pump.

Most batch filters are batch operated but continuous filters are also available. However, owing to the difficulty in removing the cake they are mechanically very complex and expensive so mainly applied in fine chemical processes where added value to product is high.

There are two constraining factors that determine the duration of filtration cycle:

- For cake filtration it is the volume available for cake build up and once the volume is filled the cycle must terminate even if the permissible pressure was not reached.
- When the solids are fast blinding, the cycle must terminate once the permissible pressure has been reached regardless of cake thickness.



The filtration rate is influenced, in broad terms, by the properties of the slurry. The trend is that the rate goes up with increased pressure, coarser particles, particle distribution with high uniformity, non slimy or non gelatinous solids, non-compressible cakes, lower liquid viscosity and higher temperatures.

2. Filtration Analysis:[2][3]

$$Q = \frac{dV}{dt} = \frac{\Delta P\, A}{\mu\left(\frac{\alpha_{ave} c V}{A} + R_m\right)}$$

Q = Flow Rate of Eluent
t = time of filtration
DP = pressure drop
A = effective area of filtration
μ = viscosity of filtrate
aave = average specific cake resistance
c = kg of dry cake per volume of filtrate
V = volume of filtrate
Rm = medium resistance
Assumptions: Constant pressure
Constant area
Ignore gravity
Parabolic Data Analysis:

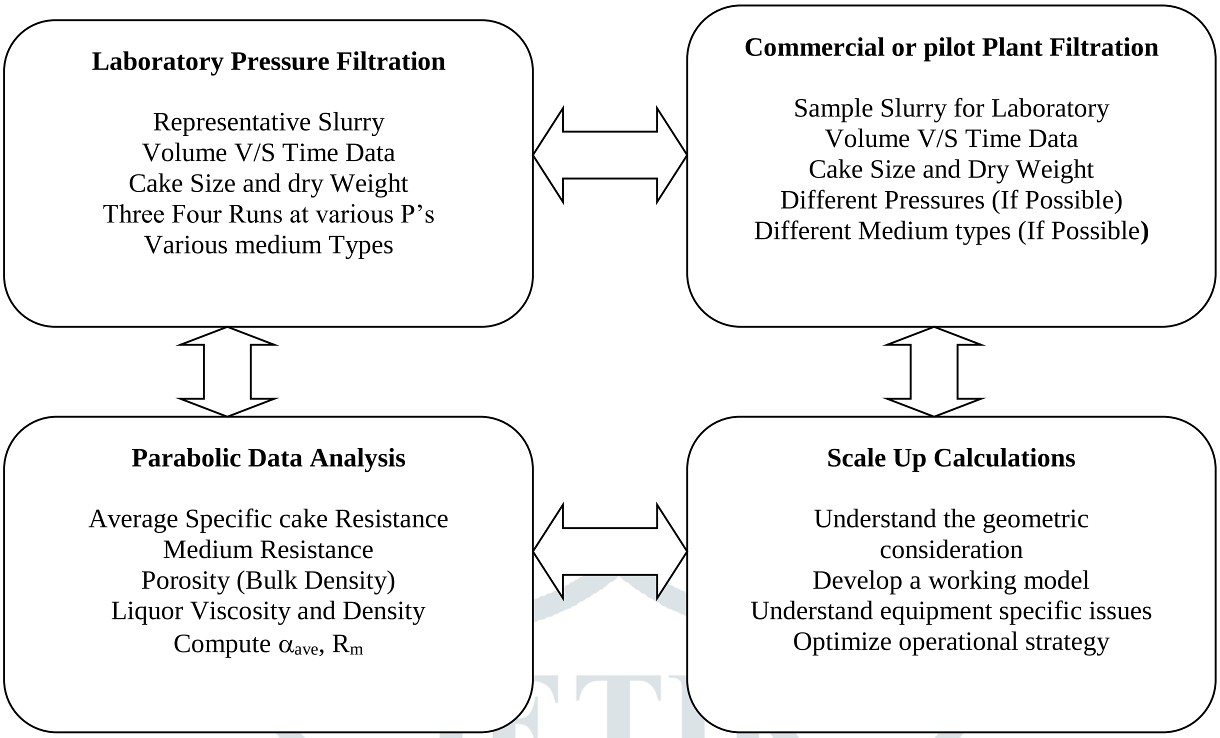
$$t = \alpha_{ave}\left(\frac{\mu c}{2A^2 \Delta P_{driving}}\right)V^2 + R_m\left(\frac{\mu}{A\Delta P_{driving}}\right)V$$

Rearranging

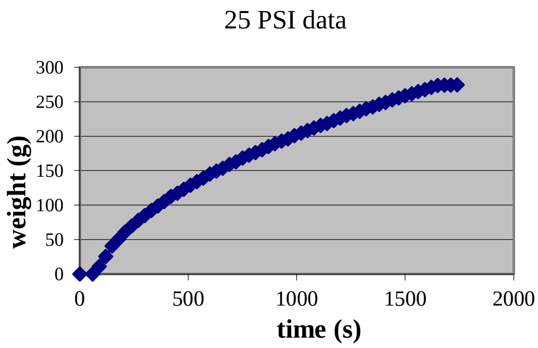
$$\frac{t}{V} = \alpha_{ave}\left(\frac{\mu c}{2A^2 \Delta P_{driving}}\right)V + R_m\left(\frac{\mu}{A\Delta P_{driving}}\right)$$

Plot t/V vs V – Linear
Slope – proportional to average specific cake resistance
Intercept – proportional to medium resistance

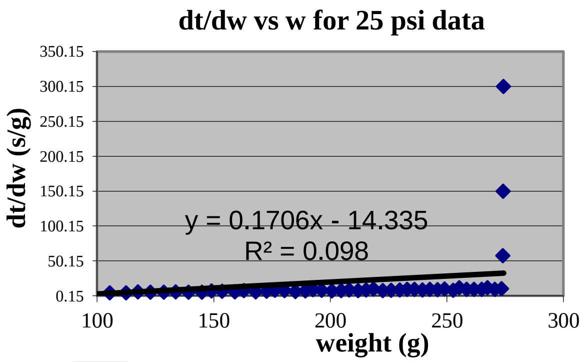
3. Experimental Method and Analysis:[3][6]



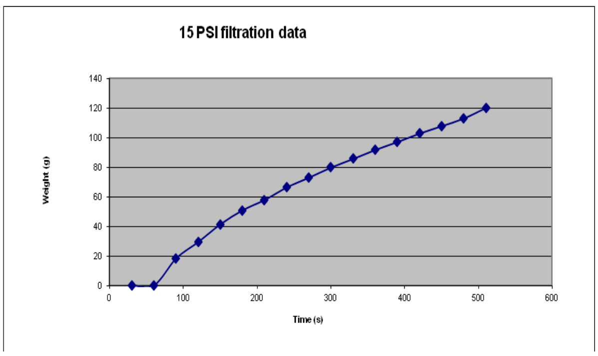
4. Filtration for different pressure:



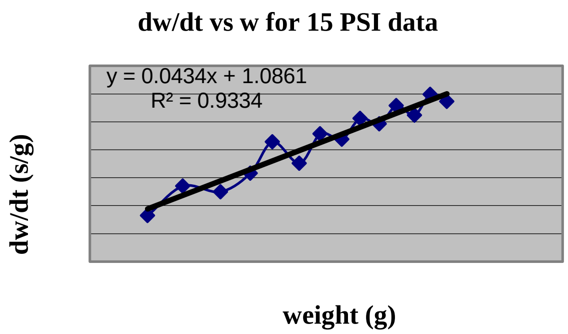
Time V/s Weight graph for 25 psi pressure



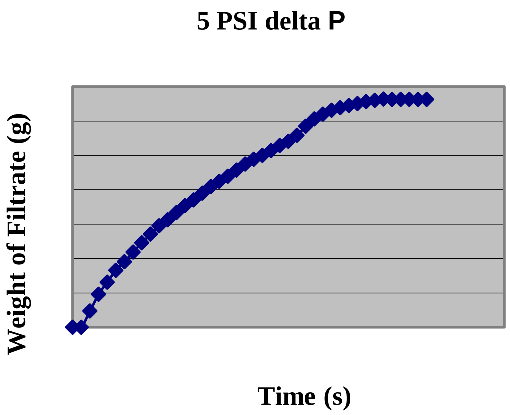
Weight v/s dt/dw graph for 25 psi

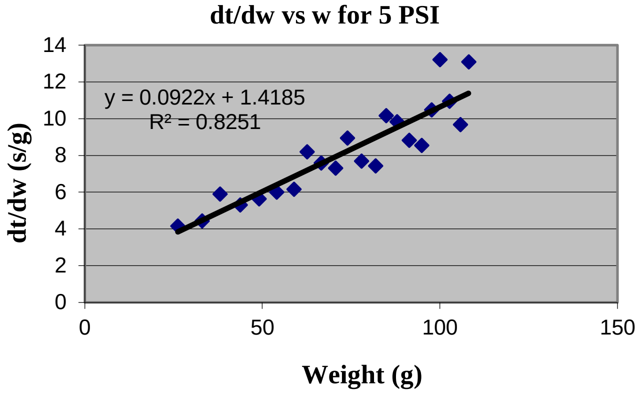


time v/s weight graph at 15 psi



Weight v/s dw/dt graph at 15 psi





time v/s weight for 5 psi **weight v/s dt/dw for 5 psi**

5. Specific cake resistance calculation:[2][3][4]

Slope ↓ Intercept ↓

$$\frac{dt}{d(\rho V)} = \left(\frac{\mu \alpha_{ave} c}{\rho^2 \Delta P A^2} (\rho V) + \frac{\mu R_m}{\rho \Delta P A} \right)$$

5.1. Properties data

For 5 psi Product			Unit
	Intercept=	0.01	s/g
	Slope =	0.092	s/g
	Viscosity μ=	1×10^{-3}	kg/m-s
	C=	61.12	kg/m^3
	Ao =	2	m^2
	DP =	34473.78	N/m^2
	Density ρ=	0.958	g/cm^3

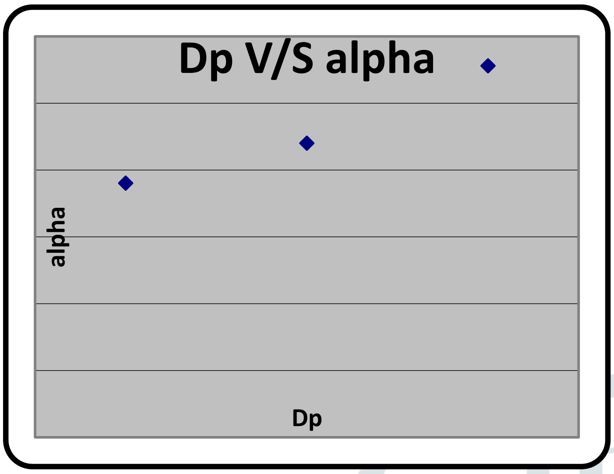
$$slope = \frac{\mu \alpha_{ave} c}{\rho^2 \Delta P A^2}$$

By keeping all this values in above equation:
αave = $1.90 \text{ X } 10^{10}$ m/kg
Intercept = $\frac{\mu R_m}{\rho \Delta P A}$
Rm = 6.61 105 m-1

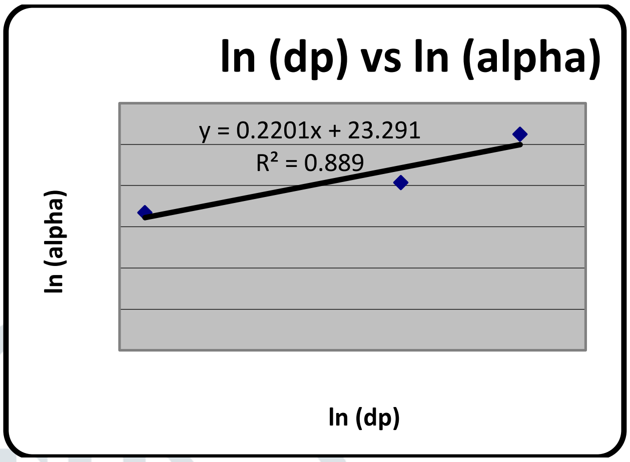
Same Way calculating α_{ave} for 15 as well as 25 Psi

5.2. α(Specific cake resistance) & Pressure

DP	alpha	ln(p)	ln(a)
5	1.90E+10	1.609438	19.06253
15	2.20E+10	2.70805	19.20914
25	2.78E+10	3.218876	19.44313



Dp v/s alpha



ln(dp) v/s ln(α)

$$\alpha = \alpha_o (\Delta P)^s$$

$$\ln \alpha = \ln \alpha_o + s \ln(\Delta P)$$

So, S=0.220
So from graph,
Slightly compressible
Expect:

- Some effect of filtration flux
- Likely acceptable filtration in centrifuge

6. Result:

For 50 kg Product:

$$t = \alpha_{ave} \left(\frac{\mu c}{2A^2 \Delta P_{driving}} \right) V^2 + R_m \left(\frac{\mu}{A \Delta P_{driving}} \right) V$$

By keeping all this value in above shown equation:
t= 7821.66 s
= 130.3611 min
= 2.172685 hr

7. Conclusion:

In conclusion, the research presented in this paper underscores the critical importance of scale-up calculations in the efficient and effective implementation of filtration processes across various industries. Filtration, as a fundamental unit operation, plays a pivotal role in the separation of solids from liquids, and the ability to accurately predict and scale up these processes from laboratory to industrial scales is paramount for achieving desired outcomes.

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