Utilizing particle capture models and genetic algorithms to maximize cross-flow filter permeate volumes

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Summary

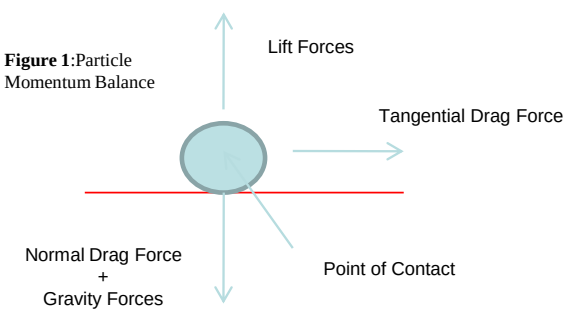
A model that relates permeate flux to particles retained on the membrane surface was developed from Foley et al. [**1**] and Lu and Ju [**2**]. The equation for this model is given below and utilizing this model with the appropriate parameters permeate rates were matched with experimental data.

The developed permeate flux model will then be utilized within an optimization scheme to ask what benefit is there to allowing the set-point axial velocity and trans-membrane pressure differential to vary to maximize the volume of permeate per a unit time.

Problem Statement

The purpose of this work was to determine the benefit of allowing the set-point, axial velocity and trans-membrane pressure differential, to vary to maximize permeate volumes. A precursor to asking this question is to provide a model that relates permeate volumes to particle size capture, which is shown below.

Figure 1:Particle Momentum Balance



$$Q_p = \frac{.425 f u^2}{\phi v \tan\theta} d_p - \frac{(\rho_p - \rho_s)}{18\mu\phi} g d_p^2 + \frac{15.25 f^2 u^4}{4608 v^3} d_p^3$$

Model Inputs

Concentrations		
Phi©	1.00E-02	
Phi(b)	2.00E-04	
Filter Parameters		
Rm	1.00E+08	[1/m]
Diameter	0.0127	[m]
Tan(theta)	0.55	
Phi	1.48E+01	
Fluid Mechanics		
mu	0.005	[kg/m-s]
dP	158,027	[Pa]
rho(l)	1,000	[Kg/m^3]
rho(s)	1,190	[Kg/m^3]
nu	5.E-06	[m^2/s]
u	4.93	[m/s]
Re	12522.2	
f	0.045	
PSD Parameters		
dmin	3	[micron]
dmax	10	[micron]
dp(ave)	6.50	[micron]
a1	100	"adjustment parameter"
a2	6.5	"mean"
a3	2	"variance"
Numerical		
dT	15	[s]
dp(0)	16.08259	"microns"

Results

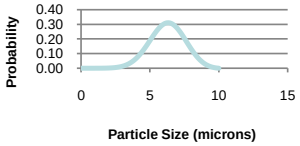


Figure 2: Particle Size Distribution

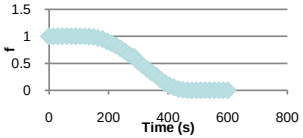


Figure 3: Time vs. Percent Capture

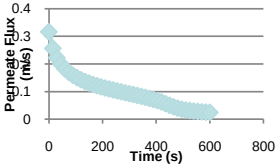


Figure 4: Time vs. Permeate flux

Discussion/Conclusions

There were three parameters that were difficult to estimate: angle of repose, volumetric fraction of solids in cake, and friction factor using existing models. The first two were never successfully determined and so additional experiments are required.

Even given these challenges, a model was determined that matches the experimental data and can be utilized as the basis to a model effort that would include an optimization scheme to maximize permeate volumes per a unit time by varying the set-point.

Acknowledgement

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1. Foley, Malone and MacLoughlin (1995). “Modeling the effects of particle polydispersity in crossflow filtration.” *Journal of Membrane Science*, v. 99, pp. 77 to 88.
2. Lu and Ju (1989). “Selective particle deposition in cross-flow filtration”, *Separation Science and Technology*, v. 24, n. 7/8, pp. 517 to 540.

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