CHBE 344 Homework Assignment #3

Due: 26 October 2018 at 4pm

Problem 1 (15 points):

Consider a bench-scale, packed-bed reactor (90.0 mm diameter, 1.00 m height) containing silica sand ($\phi = 0.498$; $\Psi = 0.730$) and sulfate-reducing bacteria for removing sulfate, arsenic, and heavy metals from water (998 kg/m^3; 1.13 cP) used in a mining operation:

a) For of flow rate of 28.2 mL/min:

   i) Calculate the pressure drop for a nominal (Sauter-mean) diameter of 2.0 mm of the sand particles.
   ii) Plot the pressure drop across the reactor as a function of the nominal diameter of the sand particles from 50 μm to 5 mm. (Assume that the packing fraction remains unchanged).
   iii) Discuss the trade-offs related to pressure drop, porosity, and surface area involved with selecting a particle size for the sand to use in the reactor.

b) Suppose that you want to exchange the sand particles for a new synthetic packing material made up of spherical particles with a Sauter-mean diameter of 203 μm. Calculate the porosity of the packed bed if the pressure drop for the same flow rate is found to be 511.5 Pa.

Problem 2 (15 points):

A cake filter is used in a batch-filtration process to remove a material that has a specific cake resistance of $\alpha = 7.95 \times 10^{10}[m/kg]\left(1 + 4.15^{-3}\left(\Delta P[kPa]\right)^{0.74}\right)$. The filtration unit for this system is operated at a constant volume flux of 2.45 L/ft2/min from the start of the run until the pressure drop reaches 472 kPa and then at a constant pressure drop of 472 kPa until a total of 1,400.0 gal of filtrate has been processed. The slurry of this material in water (1.01 cP) is giving 1.25 kg of cake solid per cubic foot of filtrate.

For a 1.00 inch thick filter with an area of 71.7 ft^2 and permeability of 6.94×10^{-12} ft^2:

a) Calculate the total filtration time (in the most logical units).

b) Plot the pressure drop (in kPa), volume flux of filtrate (in m/s), and cake mass (in kg) as a function of time (in the same units as part a)).

You may assume that the total pressure drop is approximately equal to the cake pressure drop when calculating α.

Problem 3 (10 points):

Consider 157 μm particles of limestone (ρ = 2,800 kg/m^3) settling in water at (998 kg/m^3; 1.00 cP) in a 0.25 m (inner) diameter centrifuge.

a) Calculate the terminal velocity at 50 g.

b) Plot the radial component of the terminal velocity at a position 5.0 cm from the outer wall of the centrifuge as a function of the rotation speed from 60 RPM to 4000 RPM.

Problem 4 (10 points):

Consider a continuous cylindrical centrifuge with an inner wall diameter of 575 mm and a depth of 375 mm operating under the following conditions?

- $\rho_{liquid} = 1205$ kg/m^3
- $\rho_{solid} = 1610$ kg/m^3
- $\mu_{liquid} = 1.95$ cP
- Thickness of liquid layer = 25.0 mm
- Rotation rate = 1200 RPM

a) Calculate the separation capacity in m^3/h for a particle cut size of 35 μm, assuming spherical particles.

b) Plot the separation capacity as a function of particle cut size for diameters ranging from 5 μm to 1 mm.