CHBE 344 Homework Assignment #2

Due: 5 October 2018 at 4pm

Problem 1 (10 points):

The sieve analysis data given in the data file (HW2-1 Data.csv) represent the mass fractions retained on a set of screens in the Tyler sieve series (see slides for sizes). These analyses were done on the feed, accepts, and rejects streams from an industrial screen.

Do not confuse the industrial screen with the Tyler sieve screens. The latter are only an analytical tool used to get the size distributions of the particles in the streams entering and leaving the industrial screen. The industrial screen is 10 mesh i.e. it has 10 openings per inch and the wires making up the screen have diameters of 0.0401 inches. Calculate the overall effectiveness of this screen. **HINT:** You will likely need to interpolate the data.

Problem 2 (15 points):

Consider a spherical silica particle ($\rho = 2650$ kg/m^3) settling in a liquid:

a) For a 105 μm diameter particle:
   i) Plot the terminal settling velocity as a function of liquid viscosity from 1 cP (water) to 10 Pa-s (extra-heavy crude oil)
   ii) Calculate the terminal settling velocity for the particle in vegetable oil (44.5 cP)

   You may assume that the liquid density is 935 kg/m^3 in each case.

b) For West Texas Intermediate crude oil (4.91 cP; 827 kg/m^3) as the liquid:
   i) Plot the terminal settling velocity as a function of particle size from 10 μm to 10 cm
   ii) Calculate the terminal settling velocity for a 1 mm particle

c) Calculate the time and distance traveled to reach 90% of the settling velocity for the two calculations (part ii) for the previous two situations. Is it reasonable to ignore this initial acceleration period when designing a settler for these cases?

Problem 3 (15 points):

Particles of sphalerite ($\rho = 4.00$ g/cm^3) in carbon tetrachloride (CCl4) at 20C ($\rho = 1.594$ g/cm^3; $\mu = 0.913$ cP) are settling in a continuous flow sedimentation unit with cross-sectional settling area of 9.75 m^2. The feed stream (20.2 L/min) is well-mixed and contains a volume fraction of 0.198 particles ranging in diameter from 1.00 μm to 5.00 mm.

a) Assuming ideal settling of spherical particles, plot the fraction of particles (of a given size) that will be removed by the sedimentation unit as a function of particle size. You may assume the following relationship holds for hindered settling velocity:

$$u_t = u_{t0}\,(1-\phi)^n\,; \qquad n = 3.575 - 1.075\tanh\left(0.6516\left(\log\left(Re\right) - 1.153\right)\right)$$

b) Assuming that the sphalerite particles have the same size distribution as the feed stream in Problem 1, calculate the mass fraction of particles in each of the output streams from the sedimentation unit. You may take the average particle diameter for the particle size on each sieve tray.

Problem 4 (10 points):

A mixture of silica and galena is to be separated in an elutriator. The galena ($\rho = 7.50$ g/cm^3) has a maximum diameter of 725 μm and a minimum diameter of 55 μm. The silica ($\rho = 2.65$ g/cm^3) has diameters in the range 325 μm to 7.5 μm and causes substantial processing problems if it is not removed by the classifier. The only classification fluid available is water and both particles have sphericities of 0.806.
Note that Haider and Levenspiel (1988) have performed curve fitting on data for isometric particles of various sphericities and suggest the following expression for the drag coefficient:

$$C_D = \frac{24}{Re}\left(1 + ARe^B\right) + \frac{C}{1 + D/Re}; \qquad Re < 2 \times 10^5$$

Ψ	A	B	C	D
1.000	0.1806	0.6459	0.4251	6880.95
0.906	0.2155	0.6028	0.8203	1080.835
0.846	0.2559	0.5876	1.2191	1154.13
0.806	0.2734	0.5510	1.406	762.39
0.670	0.4531	0.4484	1.945	101.178
0.230	2.5	0.21	15	30
0.123	4.2	0.16	28	19
0.043	7	0.13	67	7
0.026	11	0.12	110	5

a) Calculate the elutriation velocity needed to ensure that all the silica is removed from the galena.

b) Is a complete separation possible?

c) If complete separation is not possible, what is the maximum size of galena particle carried over with the silica?