CHBE 344 Homework Assignment #1

Due: 21 September 2018 at 4pm

Problem 1 (10 points):

a) Show that the volume fraction or density of an assembly of monodisperse close-packed spheres is 0.74, or 74%, and that of cylinders is 91%. Give your answers as exact expressions and show the details of your derivations.

b) Are there any shapes that would give packing densities higher than 91%? If so, list several examples. If not, state why not.

Problem 2 (20 points):

For an internship project an undergraduate student was asked to do a particle-by-particle analysis of several representative samples of a particulate material. The student measured the volume, mass, largest Feret diameter, and smallest Feret diameter for over 1000 particles and this data is provided in a data file (HW1-2 Data.csv) on the course website. Use the data generated by the student to do the following:

a) Plot distribution functions for the following quantities and give the mean, standard deviation, skewness, and kurtosis for each:

   i) particle density
   ii) equivalent spherical particle diameter based on volume
   iii) largest Feret diameter
   iv) particle aspect ratio

b) Calculate the following quantities and briefly describe a specific scenario when each would be useful to know:

   i) Sauter mean diameter (surface area weighted) assuming the particles are cylinders with diameter and length defined by the smallest and largest Feret diameters respectively
   ii) D[4,3] (volume weighted) assuming the particles are spheres
   iii) D_{50} for the smallest Feret diameter
   iv) Mass weighted values of D_{10} and D_{90} assuming the particles are spheres

Note, you may wish to plot some of the distributions on a log-scale.

Problem 3 (10 points):

A material is crushed in a Blake jaw crusher such that the average size of particle is reduced from 60 mm to 10 mm with the consumption of energy of 13.7 kW/(Kg/s). Generate plots of the consumption of energy needed to crush the same material from an average starting size of 75 mm to final average sizes ranging from 50 to 5 mm, and give the value of the energy consumption to reach 5 mm:

a) assuming Rittinger's law applies

b) assuming Kick's law applies

c) Which of these results would be regarded as being more reliable and why?

Problem 4 (10 points):

A hot solution of $Ba(NO_3)_2$ from an evaporator contains 31.2 wt% $Ba(NO_3)_2$ in water and is fed to a crystallizer where the solution is cooled in order to generate a large number of small crystals. The initial solution temperature is 365K and approximately 1% of the original water content is lost due to evaporation during cooling for every 10K of cooling. Assuming that the solubility of $Ba(NO_3)_2$ in weight percent is well approximated by the following polynomial with T in Kelvin:

$$9.64 \times 10^{-4}T^2 - .3284T + 22.718 \tag{1}$$

a) Plot the percentage of $Ba(NO_3)_2$ removed as a function of the final cooling temperature from 365K down to 273K

b) Calculate the percentage of $Ba(NO_3)_2$ removed at 290K

c) Explain the difference between homogeneous and heterogeneous crystallization and justify which method should be used here.