Separation Processes, ChE 4M3, 2012

Assignment 3

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Objectives: Solid-fluid separation systems: particle size characterization, centrifuges, and cyclones.

Question 1 [6]

Calculate the sphericity of a needle-shaped rectangular object whose sides are in the ratio $1 : 1 : x$, where x is any value between 1 and 10. Plot the result as x vs sphericity (y-axis).

Question 2 [10]

Plot the differential and cumulative analysis (only show the percent passing curve) for the following sieve test results:

Mesh number	Mass retained [g]
6	0.0
8	8.8
12	21.3
16	138.2
20	211.6
30	161.7
40	81.6
50	44.1
70	28.7
140	13.2
170	9.6
230	8.8
Pan	5.2

Question 3 [4]

Explain why it is possible to operate most cyclones upside down, or rotated at any angle for that matter. Also explain why some centrifuges are mounted so they spin along a horizontal rather than vertical axis.

Question 4 [20]

In class we considered a very small laboratory tubular bowl centrifuge used to separate bacteria from a fermentation broth:

- $r_1 = 16.5$ mm
- $r_2 = 22.2$ mm

- bowl height of 115 mm
- operated at 800 revolutions per second

We calculated the two different throughput flow rates, Q, when integrating between:

- height 0 and h and the particle travelling from $r = r_1$ to $r = r_2$ in this time; called Q_{max}
- height 0 and h and the particle travelling from $r = r_1$ to $r = \frac{r_1 + r_2}{2}$; called Q_{cut}

1. Calculate the Σ value for this laboratory centrifuge.
2. We are looking at scaling up from the lab to a larger scale. If we have an existing pilot-plant scale tubular bowl centrifuge, what volume of the same broth can we separate per day? The pilot plant centrifuge has a height of 30 cm, an inner weir radius of 5 cm and an outer radius of 10 cm. It can be operated between 0 and 20,000 revolutions per minute. Recall the particles in the broth had an estimated density of 1040kg.m^{-3} and a diameter of 0.7 μm. The broth had a density of 1010kg.m^{-3} and viscosity of 0.001 $\text{kg.m}^{-1}.s^{-1}$.
3. In reality the bacteria are not of uniform size. Plot operating curves that shows the smallest particle diameter we can remove from the broth on the pilot scale unit. Show the result as a function of the throughput flow rate Q_{cut}, with operating curves at 5000, 10000, 15000 and 20000 rpm. These plot will help the engineering team responsible for scale-up select a flow rate and operating speed to remove the smallest diameter particle required with minimum energy cost.

Question 5 [20]

A cyclone is being fed with a dust-laden stream at a rate of 200 kg solids per hour, with most of the solids leaving in the underflow at about 130 kg solids per hour. These streams were sampled for a period of time and using screens, the following size analyses were performed:

Mesh number	Mass retained from feed [g]	Mass retained from coarse stream [g]
20	0	0
30	21	66
35	32	84
40	38	87
50	19	32
60	14	10
Pan	11	4

1. Plot the differential analysis curve for both streams, superimposed.
2. Calculate the cut size.
3. Describe one way you could **quantify** the cut's sharpness.

END