CHL 332 Fluidization Engineering

Major: May 3, 2008

30 marks **Open Notes** **2 hours**

There are 6 questions in this test, printed on both sides of paper.

Answer short answers to questions 1-4 (less than a page of your answer book). Questions 1-4 each carry 4 marks. Question 5 and 6 are worth 7 marks each.

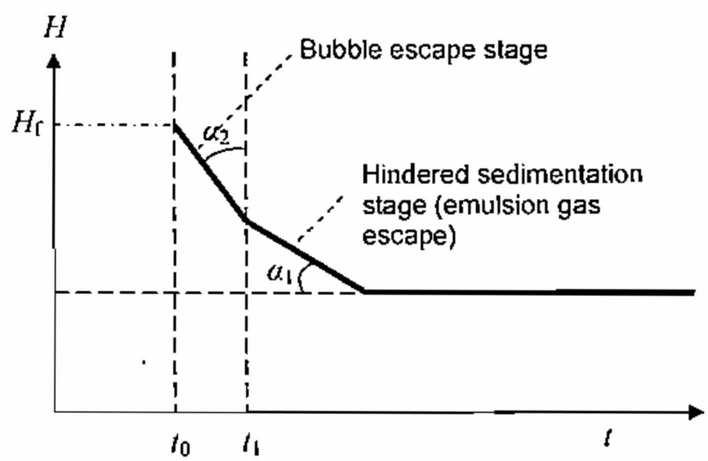
1. For a fast gas-solids chemical reaction, explain precisely why a fluidized bed is a better contactor than a packed bed. If the catalyst is rapidly deactivating, then what options do we have for smooth process operation if we are only allowed to use a packed bed (instead of a fluidized bed)?

2. Explain why a bubble in a fluidized bed is "mushroom-shaped" most of the time? Why are there short-lived and random deviations to this basic shape for some bubbles?

3. Why are gravitational instabilities formed in homogeneously fluidized beds during bed expansion but not during bed contraction? Explain.

4. State the main assumptions of the "two-fluid concept" as applied to fluidized beds. From the final "perturbation equations" that are obtained using this concept for a homogeneously fluidized bed, how does one conclude that such a bed is always unstable. (No need to present full derivation, simple state the final equations and expressions and explain.)

5. The bed collapsing technique is an important experimental method to determine such hydrodynamic properties such a bubble velocity, emulsion phase gas velocity, bubble fraction and emuslion phase voidage. In such an experiment, the bed is fluidized at a given gas velocity and then the gas supply is suddenly turned off. The variation of total bed height H_f with respect to time is recorded. A typical variation curve for Group A particle is shown in the figure below.



As can be seen in the figure, the curve reflects two stages of gas excaping behavior, *i.e.*, the bubble escape stage ($t_0 < t < t_1$) and the hindered sedimentation (or emulsion gas escape) stage. During the first stage, all the bubbles and part of the gas in the emulsion phase escape the bed. The first stage is characterized by rapid, linear, bed collapse or linear decrease of bed height with time. During the second stage, the gas in the emulsion phase continues to escape. The relationship of bed height and time is linear in this stage until the bed approaches the packed bed state.

On the basis of this information provided, determine if possible, determine U_{bb}, ε_{em}, ε_b and U_{em}.What other key assumptions are being made in your derivation of the above expressions?

6. Determine the gas flow rate in the bubble phase and emulsion phase for a fluidized bed combustor (Group B particles of coal) under the following two operating conditions: (a) T = 1,173 K, p = 1.1 MPa, D = 1.2 m, M_p = 1,600 kg, d_p = 0.51 mm, ρ_p = 2,422 kg/m^3, and U = 1.0 m/s; (b) T = 293 K, p = 0.1 MPa, all other conditions being same as (a).

Relevant formulae:

At minimum fluidization:

$$\mathrm{Re}_{p_{mf}} = \sqrt{(33.7)^2 + 0.0408 Ar} - 33.7$$

$$Ar = 150\frac{(1-\varepsilon_{mf})}{\varepsilon_{mf}^3}\mathrm{Re}_{p_{mf}} + \frac{1.75}{\varepsilon_{mf}^3}\mathrm{Re}_{p_{mf}}^2$$

Average bubble size for Group B particles:

$$d_{bb} = 0.21 H_f^{0.8}\left(\frac{p}{p_a}\right)^{0.06}\left(U - U_{mf}\right)^{0.42}\exp\left[-1.4\times10^{-4}\left(\frac{p}{p_a}\right)^2 - 0.25\left(U - U_{mf}\right)^2 - 0.1\frac{p}{p_a}\left(U - U_{mf}\right)\right]$$

Expanded bed height at high temperature (upto 1,258 K) (Cai et al., 1993):

$$\frac{H_f}{H_{mf}} = 1 + \frac{21.4\left(U - U_{mf}^*\right)^{0.738} d_p^{1.006}\rho_p^{0.376}}{\left(U_{mf}^*\right)^{0.937}\left(w_g\frac{p}{p_a}\right)^{0.126}}$$

Where w_g is the molecular weight of gas (air = 28.9) and U^*_{mf} is the minimum fluidization velocity at ambient temperature. p_a is ambient pressure.

Average bubble rise velocity:

$$U_{bb} = U - U_{mf} + 0.71\sqrt{g d_{bb}}$$