Bengal Engineering and Science University Shibpur

BE (Mech) Part IV 8th Semester Final Examination 2013

Circulating Fluidized bed technology (ME 804/3)

Answer any SIX questions

Time 3 hrs Full Marks 70

1. (a) What is a fast fluidized bed? What are the characteristics of fast beds? Show in a neat diagram the transition from pneumatic transport to fast fluidization. How does the fast fluidization get bounded by two velocities?
   (b) Find the minimum velocity for fast fluidization for 300μm sand particles at 300K and 1098K for the following conditions. The desired solid circulation rate in the fast regime is 30kg/m^{2}s. The cross-section of the bed is 0.203 m × 0.203 m. The density of the particles is 2500 kg/m^3. The gas viscosity, density and terminal velocity at 300K and 1098K are 4.49 ×10^{-5} kg/ms, 0.316kg/m^3, 2.72 m/s and 1.84 ×10^{-5} kg/ms, 1.16kg/m^3, 2.37 m/s, respectively. Calculate the terminal velocity using the standard formula.

2. (a) Draw the axial profile of cross-section average bed voidage and the radial voidage profile across the cross section of a bed.

   (b) Estimate the bed inventory in a CFB furnace operating at 1098K, and the bed voidage at 4m above a fast bed that is 20m tall. Also find the voidage at the wall at this height. ρ_p=2500 kg/m^3, U=8m/s and d_p=300μm. The secondary air is injected at the level of 3m. The bed cross-section is 2.5 m × 10 m below and 5 m × 10 m above this level. ϵ_a=0.85, ϵ_d=0.9976, a=1.0m^{-1}

3. (a) What is the mechanism of bed-to-wall heat transfer in a CFB? How do the design and operating parameters influence bed-to-wall heat transfer in a fast fluidized bed furnace? Describe in detail the theory of cluster renewal model for bed-to-wall heat transfer in CFB furnace.

   (b) A boiler panel wall of membrane type (50 mm diameter tube at 75 mm pitch) contains one 26 mm high and 3 mm thick vertical fin on each tube. Find the enhancement of heat absorption by the wall. Fin efficiency is 0.9.

4. (a) Draw the temperature-time diagram showing the sequence of events in the combustion of a coal particle.

(b) Estimate the burning rate of a 8.4 mm char particle produced from coal burning in a fast fluidized bed at 1073 K, and a 7.8% oxygen concentration. The measured surface temperature of the particle is 1143 K, and the fluidization velocity is 8 m/s. Use the kinetic rate for coal as follows:

$A'=0.0263\ kg/m^2\ (kPa)^n$ $E/R=3106K$ order of reaction, $n=0.5$

Take gas viscosity, density and molecular diffusivity as 4.5×10^{-5} kg/ms, 0.316 kg/m^3 and 1.88×10^{-4} m^2/s, respectively. The bed voidage is 0.989. Assume that the average velocity of the char particle is about 1 m/s.

5. How does sulfur capture occur in a CFB boiler? Discuss chemical reactions associated with sulfur in coal. How does sulfur retention occur in the form of calcium sulfate? Discuss calcinations, half calcinations, sulfation, reverse sulfation, reactions on single sorbent particles and reactivity of sorbents. How is selection of sorbents done?

6. What are the major steps involved in the design of CFB boilers? How are heat and mass balance done in a CFB boiler? How is the design of furnace cross-section, width and breadth ratio and furnace openings done? How are the heating surfaces of a CFB boiler designed?

7. How is the design of L-valve, loopseal and distributor plates done in a CFB boiler?

8. What is the basic difference in the principle of operation of cyclone separator and inertial separator. What are the design steps of designing the two types of separators?