Indian Institute of Engineering Science and Technology Shibpur

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

Circulating Fluidized bed technology (ME 804/3)

Answer all questions

Time 3 hrs | Full Marks 70

1. (a) 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 $30 kg/m^2s$. 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, $0.316 kg/m^3$, 2.72 m/s and 1.84×10^{-5} kg/ms, $1.16 kg/m^3$, 2.37 m/s, respectively. Calculate the terminal velocity using the standard formula.
   (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. $\rho_p = 2500\ kg/m^3$, 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. $\epsilon_a = 0.85$, $\epsilon_d = 0.9976$, $a = 1.0 m^{-1}$

2. (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.

3. (a) Draw the schematic depicting the sequence of volatile release showing how different constituents of volatiles are released during different stages of devolatilization. The vertical width of each constituent must be approximately proportional to its weight fraction in coal.

   (b) Estimate the time taken by a 3.5 mm coal particle to complete its devolatilization and volatile combustion in a bed at 845°C. Given p= 1.55 and a =3.52 at 725°C.

4. What is the mechanism of formation of nitrogen oxide in the CFB boilers ? What are the sources of NO_x ? What are the methods of reduction of NO_x including N_2O ?

5. Consider the ultimate analysis of a coal required to achieve 90% sulfur retention using a limestone that contains 90% calcium carbonate, 9% magnesium carbonate, and 1% inert material and using calcium to sulfur molar ratio of 2. The fly ash is 10% of the total ash. The surface moistures of both the coal and limestone are 7.1%. Find the stoichiometric quantities for the design of the CFB boiler. Given the following data:

X_m =1.3 %, X_{ml} =M_f =7.1 %, C = 56.59 %, H = 4.21 %, N = 0.9 %, Cl = 0.4 %, S =4.99 %, O =5.69%, ASH =20. 06 %, X_{CAO} = 0.0136, E_c = 98 %, EAC=1.2

6. Thermal capacity of a CFB boiler is 406 MW. The flue gas temperature is 143^{0}C. Sulfur capture target is 90% with a calcium to sulfur molar ratio of 2.0. Average temperature of all ashes leaving the boiler is 220^{0}C. Ash contains about 1.5% carbon. Other data are as follows.

Steam condition: 130 bar, 588^{0}C; saturation temperature, 363^{0}C; Feed water temperature, 240^{0}C.

Coal: X_m = 7.0%, C = 56.59%, H = 4.21%, N = 0.9%, Cl = 0.4%, S = 4.99%. O = 5.69%, ASH = 20.6%, HHV = 24657 kJ/kg.

Limestone: X_{caco3} = 90%, X_{MgCO3} = 9.0%. X_{inert} = 1.0%; calcium to sulfur ratio to be used to achieve 90% sulfur capture is 2.0. Combustion efficiency = 98%.

Find the principal dimensions of the furnace. Any missing data may be assumed reasonably.