Exam 23.10.2013

3. Calculate the amount (mol) and composition (%) of the flue gases with the following input data. Composition of the fuel under consideration (in wt%): C 50 , H 6.3, S 0.1, O 42.5, N 0.1 and the rest is ash. Moisture content 25 wt%. The fuel is combusted with air (21 vol % O_2 and 79 vol % N_2). Assume stoichiometric combustion (no excess air). Use 1 kg of fuel as calculation basis. Useful molecular weights (g/mol) C 12.01, H 1.01, O 16.0, N 14.01, S 32.07, CO_2 44.01, H_2O 18.02, O_2 32.0, N_2 28.01, SO_2 64.07. (5 p.)

4. a) Considering the previous problem (3), calculate the average temperature of the flue gases, using the following input values: Fuel loose density 300 kg/m^3, Heating value (as received) 14.01 MJ/kg, moisture 25 %. Wood is burned with air with the air factor 1.2. The temperature of air at inlet is 200 °C. Fuel is assumed to be at the reference temperature 25 °C. Heat loss from the combustor walls is 5 % of the thermal capacity. The capacity of the combustor is 1 MW_{th}. (4 p.)

   Averaged specific heat constants (J/molK) CO_2 51.7, H_2O 41.7, O_2 32.0, N_2 31.0, SO_2 52.1

SOLUTION

Gas composition from the material balance:

Flowrates of species in and out

Fuel in (mol)	Flue gases out (mol)	vol %
C: 0.5*1000*(1-0.25)/12.01 = 31.22	CO_2: 31.22	16.2
H: 0.063*1000*(1-0.25)/1.01 = 46.78	H_2O: 46.78/2+ 13.87 = 37.26	19.35
O: 0.425*1000*(1-0.25)/16.0 = 19.92	O_2: 32.98+19.92/2 - 42.94 = 0	0
N: 0.001*1000*(1-0.25)/14.01 = 0.053	N_2: 124.07 +0.053/2 = 124.1	64.43
S: 0.001*1000*(1-0.25)/32.07 = 0.023	SO2: 0.023	0.012
Ash: 0.01*1000*(1-0.25) = 7.5 g		
Water: 0.25*1000/18.02 = 13.87		
St. O_2: 31.22+0.5*46.78/2+0.023 = 42.94	Flue gases total 192.6	
O2 (air) = 1.0*42.94 - 19.92/2 = 32.98 ***)**		
N2 (air) = 79/21*32.98 = 124.07	Ash: 7.5 g	

***)** Stoichiometric combustion (no excess air): $\lambda = 1.0$

$\lambda = (n_{O2,A} + n_{O2,f}) / n_{O2,St.}$ → $n_{O2,A} = \lambda * n_{O2,St.} - n_{O2,f} = 1.0*3.07 - 1.42/2 = 2.36$ mol/s

Flue gas temperature from the energy balance:

Calculation basis the fuel heating value

Fuel heating value as fed (MJ/kg) = 14.01

➔ Fuel feed 1 MJ/s/(14.01 MJ/kg)*1000 g/kg = 71.38 g/s

Or if you have used 1 kg of fuel as basis, that is also ok.

Combustor heat loss: 0.05*1 MW = 0.05 MW = 5E4 J/s

Energy flowrates of species in and out

Fuel in (J/s) at reference temperature	Flue gases out (J/s)
C: $n_C*c_p*(298.15-298.15) = 0$	CO_2: $2.23*51.7*(T_2-298.15) = ?$
H: $n_H*c_p*(298.15-298.15) = 0$	H_2O: $2.66*41.7*(T_2-298.15) = ?$
O: $n_O*c_p*(298.15-298.15) = 0$	O_2: $0.614*32*(T_2-298.15) = ?$
N: $n_N*c_p*(298.15-298.15) = 0$	N_2: $11.19*31*(T_2-298.15) = ?$
S: $n_S*c_p*(298.15-298.15) = 0$	SO_2: $0.002*52.1*(T_2-298.15) = ?$
Ash: $n*c_p*(298.15-298.15) = 0$	
Water: $n_{H2O}*c_p*(298.15-298.15) = 0$	
Fuel combustion energy 1.0E6	$H_{Ash} \approx 0$
Air feed:	
$O_2 = 2.36*32*(473.15-298.15) = 1.32E4$	
$N_2 = 8.88*31*(473.15-298.15) = 4.82E4$	$H_{loss} = 5E4$

Now Energy in = Energy out (J/s)

$H_{Fuel} + H_{combustion} + H_{Air} = \Sigma H_{gases} + H_{ash} + H_{loss}$

- ➔ $0 + 1E6 + 1.32E4 + 4.82E4 = 2.23*51.7*(T_2-298.15) + 2.66*41.7*(T_2-298.15) + 0*32*(T_2-298.15) + 8.88*31*(T_2-298.15)+ 0.002*52.1*(T_2-298.15) + 0 + 5E4$

→ $T_2 = 1011400/501.6 + 298.15 = 2314.5$ K = 2041.3 °C