Lecture30: Heat balance in iron making

Contents

Exercise- I

Mention all the generated and heat output terms in the blast furnace ironmaking.

Solution:

Heat is generated by combustion of carbon. Sensible heat in blast also adds heat input. Small amount of heat may be generated by mixing of silicon in iron, reduction of FeO by CO and silicate formation.

Some heat output terms are: heat carried by slag, hot metal and gases. Heat losses by convection and radiation may be included.

Exercise-II

An iron blast furnace produces pig iron of composition $C\ 3.5\%, Si\ 1.5\%, Mn\ 0.8\%$ and rest is iron. The burden of blast furnace consists of the following materials:

Iron ore：$Fe_2O_3\ 76\%, SiO_2\ 14\%, Al_2O_3\ 9\%, MnO 1\%$

Coke: $C\ 88\%$ and $SiO_2 12\%$ .Amount 1100Kg per ton of pig iron.

Limestone: pure $CaCO_3$

The exit gas analyzes $26\%\ CO, 13\%\ CO_2$ and $61\%\ N_2$. Assume no loss of iron in slag.

Required:

a) Weight of iron ore/ton of pig iron.
b) Wt. of limestone/ton of pig iron, required to produce slag containing $36\%\ CaO$.
c) Volume of gases
d) Volume of blast based on O_2 and N_2balance.
e) Heat of decomposition of $CaCO_3$ at 298K
f) Heat content of pig iron and slag at 1700K
g) Sensible heat in gases: exit temp is 600K
h) Heat of combustion
i) Heat absorbed by Boudward reaction
j) Heat produced by reduction reactions.

Thermo chemical data

a) Sensible heat in products $H_T - H_{298}$

Product	Temperature (K)	Sensible heat kcal/kg. mole
Fe	1700	13090
C	1700	6610
Mn	1700	17840
Si	1700	20756
SiO_2	1700	22860
Al_2O_3	1700	40090
MnO	1700	1749
CaO	1700	14333
CO	600	2137
CO_2	600	2088
N_2	600	2126.

b) Heat of formation of compounds in $\frac{\text{Kcal}}{\text{kg.mole}}$

$\text{CO} = -26.4 \times 10^3$

$\text{CaO} = -151 \times 10^3$

$\text{CO}_2 = -94.45 \times 10^3$

$\text{CaCO}_3 = -289.5 \times 10^3$

$2\text{CaO}.\text{SiO}_2 = -26.4 \times 10^3$

c) Heat of mixing in kcal/kg mole.

$(\text{C})_s = (\text{C})_{\text{liquid,1wt.\%}} = 5.4 \times 10^3$

$(\text{Si})_s = (\text{Si})_{\text{l,1wt.\%}} = -28 \times 10^3$

d) Heat of combustion of $\text{CO} = 26.4 \times 10^3 \ \frac{\text{kcal}}{\text{kg.mole.}}$

e) Heat evolved/absorbed in reduction reaction

$\text{SiO}_2 + 2\text{C} = \text{Si} + 2\ \text{CO}$

$\text{Heat absorbed} = 148200 \frac{\text{kcal}}{\text{kg mole}}$

$\text{Fe}_2\text{O}_3 + \text{CO} = 2\text{FeO} + \text{CO}_2$.

$\Delta\text{H}_\text{R}^\circ = 2000 \frac{\text{kcal}}{\text{kg mole.}}$

$\text{FeO} + \text{CO} = \text{Fe} + \text{CO}_2$

$\Delta\text{H}_\text{R}^\circ = -4400 \frac{\text{kcal}}{\text{kg mole.}}$

$\text{CO}_2 + 2\text{CO}$

$\Delta\text{H}_\text{R}^\circ = +41.6 \times 10^3 \frac{\text{kcal}}{\text{kg mole.}}$ (endothermic)

Solution:

The reader should attempt to make materials balance. Here materials balance results are given:

a) $\text{Amount of iron ore} = 1770\ \text{kg}.$
b) $\text{Amount of } CaCO_3 = 518\ \text{kg}.$

$\text{Amount of slag} = 804\ \text{kg}.$

c) $\text{Volume of exit gas} = 4762 m^3.$
d) $\text{Volume of air from } N_2 \text{ balance} = 3677 m^3.$

e) Heat of decomposition of $CaCO_3$ from the $\text{data} = 228179\ \text{kcal}$ (highly endothermic). The reader should note that decomposition of $CaCO_3$ absorbs large amount of heat.

f) Heat content of pig iron and slag at 1700K.
From the thermo chemical data, heat content in $\text{pig iron} = 254134\ \text{kcal}$. This heat content of slag can be calculated from the thermo chemical data and materials balance.

$\text{Heat content in slag} = 244978.8\ \text{kcal}$

g) Sensible heat in gases
From the data: sensible heat in gases $= 479.18 \times 10^3\ \text{kcal}$
h) Heat of combustion. At the tuyere all the carbon is burnt into CO
$\text{Heat generated} = -2081.2 \times 10^3 \text{kcal}$ Exothermic

i) Heat evolved or absorbed in reduction reactions.
SiO_2 reduction to Si absorbs heat.
$\text{Heat absorbed} = 79.392\ \text{kcal}.$

Reduction of Fe_2O_3 to FeO
$\text{Heat absorbed} = 16820\ \text{kcal}$
Reduction of FeO to Fe.
$FeO + CO = Fe + CO_2$
$\text{Heat produced} = -74014\ \text{kcal}$

j) Heat absorbed by Boudward reaction
Boudward reaction
$CO_2 + C = 2CO$

is one of the most important reactions in metal extraction in general and blast furnace in iron making particular.

Heat of reaction $= 41.6 \times 10^3 \ \frac{\text{kcal}}{\text{kg mole}}$

Boudward reaction is highly endothermic.

CO_2in exit gas $= 27.64$ kg moles.

Number of CO_2 moles reduced $= CO_2$ produced by reduction of Fe_2O_3 and FeO by $CO - CO_2$in exit gas $+ CO_2$ in $CaCO_3$

From the material balance one can obtain CO_2 produced by reduction of $Fe_2O_3$and FeO by CO $=$ 25.23kg moles.

CO_2 in $CaCO_3 = 5.18$ kg moles.

Moles of CO_2 reduced by C $= 2.77$.

Heat absorbed $= 115232$ kcal.