Material balance in cupola

Operation of a cupola

Cupola is used to melt pig iron to make iron castings in foundry. Charge consists of pig iron, scrap and limestone and coke.The oxidation of the following elements takes place:

$$Si + O_2 = SiO_2$$

$$Mn + 0.5\ O_2 = MnO$$

$$Fe + 0.5\ O_2 = FeO$$

SiO_2, MnO and FeO are slagged. Loss of carbon from pig iron may occur due to oxidation of carbon. However, this loss of carbon is compensated by absorption of carbon from coke. Cupola runs intermittently.

Air is blown through the tuyeres.

In material balance, the input consists of pig iron, scrap, limestone, coke and air. Whereas output consists of cast iron, slag and exit gases CO, CO_2, N_2 etc.

In cupola melting the calculation on material balance is required to determine the amounts of various inputs and outputs such that material management can be done for smooth inflow and output of materials.

Change balance calculations

A cupola melts per hour 15 taons of pig iron of composition C 3.5%, Si 2.2% Mn 0.8% PO.7% and rest Fe; and 5 tons of scrap containing C 3,%, Si.8%MN 1.1% and PO.2%.

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The dry air used is $849.6 m^3$ measured at $313 K$ to melt 1ton of pig iron and scrap per minute.

During melting 20% of total Si charged, 15% of total Mn charged 1% of total Fe charged and 5% of C is oxidized, 19% of carbon of coke is absorbed by iron during melting. Enough $CaCO_3$ is charged to give $30\%\ CaO$ in slag. The coke is 92% C and $8\%\ SiO_2$ and weight of coke is $1/9$ of the total weight of pig iron and scrap.

Required:

a) Charge balances of cupola for 5 hr run.

b) The % composition of resulting cast iron, slag and gases.

Solution:

Pig iron $= 250\ kg|min$. and scrap $= 83.3\ kg|min$.

Metallic charge $= 333.3\ kg|min$.

Air blast $= 246.98\ m^3|min.$ out of which amount of $O_2 = 2.32\ kg$ moles

The calculation on material balance is given below

Element	Amount charged(kg)	Amount oxidized (kg)
Si	7.0	1.4
Mn	2.92	0.44
Fe	310.20	3.10
C	9.25	0.46
P	1.92	-

From the amount of element oxidized one can calculate weight of slag $= 15\ kg|min.$ (slag consists of $SiO_2 + MnO + FeO + CaO$)

Let us per form carbon and oxygen balance to calculate exit gas.

C from coke + C oxidized from pig iron + C from scrap + C in $CaCO_3$ = C in gases (1)

Oxygen from blast + oxygen from $CaCO_3$ = oxygen in gases (2)

Let x kg mole CO and Y kg mole CO_2 in exit gas

Equation 1

$x + Y = 2.9234$ (3)

$x + 2Y = 4.72$ (4)

we get $x = 1.1268$ and $Y = 1.7966$

Exit gas amount $= 1.1268 + 1.7966 + 8.7232 = 11.6466$ kg mole

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$\% CO = 9.67$, $\% CO_2 = 15.43$ and $\% N_2 = 74.90$

Exit gas volume $= 260.88\ m^3|$minute

Amount of cast iron $= 329.29$ kg | min

Charge balance for 5 hr operation

Pig iron = 75 ton   S lag = 4.5 tons

Scrap = 25 ton   cast iron = 98.8 tons

Blast $= 22 \times 10^6 m^3$ gases $= 23.48 \times 10^6 m^3$

Coke = 11.1 tons

$Ca\ CO_3 = 2.41$ tons

Illustration material balance

Pig iron and coke are charged in a cupola to produce an iron casting. The flux is pure $Ca\ CO_3$ and Kg is used/ ton of pig iron charged.The coke used 125 kg/ton of pig iron; the composition of coke is

85%C, 6% SIO_2 6% Al_2O_3 and 3% FeO

The gas from cupola contains $CO : CO_2 = 1 : 1$ by volume No carbon is oxidized from pig iron. The slag from cupola is:

FeO 12% SIO_2 45% MnO 3%, CaO 25%, Al_2O_3 15%

The cast iron produced carries 3.8% C, besides some Mn and S.

Required per ton of pig iron:

a) Weight of slag

b) Volume of air consumed in oxidizing Si Mn and Fe

c) Volume of air oxidation of C of coke.

d) Volume and % composition of gas

Solution:

Al_2O_3 balance given weight of slag =50 kg (a)

To find amount of air, we have to find oxygen of air used to oxidize Si, Mn and Fe.

Si oxidized $=$ Si in charge $-$ Si in slag

O_2 required for Si oxidation $= 0.25$ kg mole

O_2 required for Mn oxidation $= 0.011$ kg mole

O_2 required for Fe oxidation $= 0.0156$ kg mole

Volume of air consumed in oxidation $= 29.504 m^3$ (b)

Volume of air for oxidation of carbon of coke can be found one we know CO and CO_2. Since C oxidizes to CO and CO_2.

Let Y kg mole $CO + CO_2$ in exit gas

$\therefore$ exit gas : $0.5Y$ kg mole CO and $0.5Y$ kg mole CO_2

Carbon and oxygen balance: Let x kg mole of oxygen is required for oxidation of carbon of coke

$8.854 + 0.26 = 0.5Y + 0.5Y$ (1)

$x + 0.411 = 0.75$ (2)

Solving equations 1 and 2 we get

$x = 6.4245$ and $Y = 9.114$

Volume of air $= 685.28 m^3$ (c)

Volume of gas $= 768.5 m^3$

$CO = 13.28\ \%, CO_2 = 13.28\ \%\ N_2 = 73.44\ \%$ (d)

References

1. Rosenquist: Principles of extractive metallurgy
2.Butts: Metallurgical problem