

## **Lecture 26: Iron making in blast furnace**

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**Key words:** Iron making, blast furnace, coke making, by product coke oven, adiabatic flame temperature

### **Preamble**

Blast furnace iron making is an example in which both unit processes that is reduction of iron oxide and smelting to separate liquid pig iron from slag is done simultaneously in a single reactor. Height of the blast furnace is around 25 to 30m. It must be mentioned that blast furnace is a very efficient reactor both in terms of heat and mass exchange between solids and gases.

### **Blast furnace operation**

In the blast furnace burden (consists of iron ore sinter/pellets +coke +limestone/lime) at 298K is charged from top. During its descent, there occurs heat and mass exchange with the hot gases which are moving up. Hot gases comprise of CO, CO<sub>2</sub> and N<sub>2</sub>. Thus blast furnace is a counter- current heat and mass exchange reactor.

In approximately 75% of the total height of the blast furnace (i.e. from top to bottom of stack), reduction of iron oxide to FeO and decomposition of limestone occur. Burden permeability is very important for the smooth operation.

Burden permeability is controlled essentially by coke, since coke is the only component of the burden which is fused at the tuyere level. Rest of the components says Fe<sub>2</sub>O<sub>3</sub> and limestone loses oxygen and hence there occurrence changes in size and shape during decent.

Blast furnace cannot work without coke. Since coke is not a natural resource, coke making is an integral part of blast furnace iron making. In view of the importance of coke, let me discuss coke making.

### **Functions of coke**

- Source of thermal energy
- Source of chemical energy
- Coke maintains permeability of the burden

Strength reactivity, chemical composition etc. are the important properties

Coke consumption varies from 500 – 550 kg/ton of hot metal. Modern blast furnaces with pulverized coal injection work with 300 – 350 kg/ton of hot metal.

### **Coke making**

In this lecture a very brief discussion on coke making is given. Readers can see the references given at the end of this lecture.

### **How coke is produced**

Coke is produced by heating coal to high temperature ( $T \approx 1000 - 1100^\circ\text{C}$ ) out of contact of air until all volatile matters are removed. The process is called “carbonization” or “Destructive distillation of coal”.

Coal consists of complex organic compounds in which C, H, N, O, and S atoms are bonded together. As a result of heating these bounds are broken and new bounds are formed like CO,  $\text{H}_2\text{S}$ ,  $\text{NH}_3$ ,  $\text{CO}_2$ ,  $\text{H}_2$ ,  $\text{CH}_4$  and other complex hydrocarbons like  $\text{C}_6\text{H}_6$ ,  $\text{C}_2\text{H}_4$  etc.

The mass of coal during heating fuses and becomes plastic. It swells during coking and then r solidifies. The structure of coke depends much on fusion, swelling and re-solidification. Difference in behavior of different types of coal account for the difference in structure of coke. For example non coking coal may decompose without becoming plastic at any stage. Mixing of two different varieties of coal i.e. non-coking coal with coking coal result in control over coke properties.

### **By product coke-oven**

Metallurgical coke (coke used in blast furnace iron making) is produced in by product coke ovens. By – product coke ovens are flexible in treating different types of coal and to control the coke properties.

Coke is charged batch wise into silica lined or refractory lined retorts and these retorts are heated externally by burning gaseous fuels. Note that retorts are heated indirectly and coal is heated through heat transferred from the walls of the retort. Coal near the wall of the retort is heated faster than coal near the center. As a result, coke near the walls swells much earlier than coal at the center. Therefore, proper distribution of coal in the retort would be desirable.

The volatile matter from the coal is collected in the byproduct recovery plant where by product are separated from each other. It takes around 18 hours to convert one batch of coal into coke. Coke is discharge from the other end of the retort mechanical hopper into a car, were it is wet quenched.

Note that hot coke so produced cannot be used directly into blast furnace hence coke is cooled to room temperature. During wet quenching of coal considerable amount of sensible heat is lost and pollutants are discharged in atmosphere. The aspect of coke making is dealt separately in next lecture with a quantitative illustration.

The quality of coke depends both on temperature and rate of heating. Metallurgical grade coke is produced at temperature higher than 1000°C.

Among the by-products, coke oven gas possesses both sensible heat and potential energy. Coke oven gag is used as a fuel to heat the furnace and also in heating the coke oven. The leakage of atmospheric air into coke oven must be avoided as the air causes oxidation of C and results in decrease in yields.

### **Materials balance calculation procedure in coke making**

In coke making coal of certain composition is carbonized in a by-product coke oven. As a result of carbonization, products and by-product are produced. Main product is coke, whereas by-products are coke oven gas and tar.

Basis of calculation: one may take 1 kg coal, 100kg coal or 1000kg coal.

Amount of coke is determined by ash balance, namely if W kg is amount of coke then ash balance is

$$A_1 \text{ 1000/100} = A_2 W/100 + A_3 \times \text{wt. of tar/100}$$

$A_1$  is the amount of ash in coal,  $A_2$  and  $A_3$  are amounts of ash in coke and tar respectively. By knowing weight of tar, W can be calculated.

Amount of coke oven gas can be calculated by carbon balance:

$$\text{C from coal} = \text{C in coke} + \text{C in tar} + \text{C in coke oven gas}$$

### **Heat balance:**

For heat balance calculations, reverence temperature of 298K is normally selected.

Heat balance at steady state is

$$\text{Heat input} = \text{Heat output} + \text{Heat loesses}$$

In coke –making heat input is the calorific value of coal and calorific value of coke- oven gas calorific value of coal and of any other solid fuel can be determined by Dulong formula:

$$\text{GCV} = 339\%C + 1427(\%H - \%O/8) + 93\% S \text{ kj/kg}$$

$$\text{NCV} = \text{GCV} = 24.44(9\%H + \%M) \text{ kJ/kg}$$

GCV is gross calorific value and NCV is the net calorific value.

Heat output consists of

- (i) Sensible heat in coke:

It can be determined by  $W C_{pc}(T_{\text{coke}} - 298)$  in Kcal or kJ, where  $W$  is mass of coke,  $C_p$  is specific heat of coke and  $T_{\text{coke}}$  is temperature of coke discharged from coke oven.  $C_{pc}$  is 0.359 kcal/kg°C.

- (ii) Sensible heat in coke oven gas: it may be calculated by  $Y C_{pg}(T_g - 298)$  in kcal or kJ, where  $C_{pg}$  is specific heat of coke oven gas. Its value may be taken as 0.44 kcal/m<sup>3</sup>°C.
- (iii) CV of coke and tar can be calculated by Dulong formula.
- (iv) CV of coke-oven gas is the summation of heat of combustion values of all combustible components in coke-oven gas as illustrated on lecture 2.

Heat balance calculations disclose

- a. Distribution of heat energy in products and by-products.
- b. Sensible heat available in products and by-products.
- c. Heat losses can be determined from difference between heat output and heat input values.

### Conclusions:

In this lecture a brief description of blast furnace ironmaking is given so that one can proceed to perform material and heat balance. Coke is an integral part of blast furnace ironmaking. Material and heat balance is discussed in lecture 27.

### References:

R.H. Tupkary: Introduction to modern ironmaking