Lecture 4

Production of secondary fuel

Coke-making

Secondary fuels are those which do not occur in nature but they are produced from primary (natural reserves) reserves to meets certain specific requirements. It must be clearly noted that coke does not occur in nature.

One of the important secondary fuels is coke. Coke is an important raw material in the blast furnace iron-making. It is a source of chemical and thermal energy in the blast furnace. Coke also helps maintaining permeability of the burden which is required for flow of gases ascending upwards in the blast furnace. It must be clearly noted that coke does not occur in nature.

How coke is produced

Coke is produced by heating coal to high temperature (T = 1000-1100°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 bonds are broken and new bonds are formed between atoms of elements like CO, H₂S, NH₃, CO₂, H₂, CH₄ and other complex hydrocarbons like C₆H₆, C₂H₄ etc.

The mass of coal during heating fuses and becomes plastic. It swells during coking and then resolidifies. The structure of coke depends much on fusion, swelling and resolidification. Difference in behaviour 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 centre. As a result, coke near the wall swells much earlier than coal at the centre. Therefore, proper distribution of coal in the retort would be desirable.

The volatile matter from the coal is collected in the by product 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 by mechanical hopper into a car, where 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. This 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 gas 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 yield.

Material balance 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-products are produced. Main product is coke, whereas by-products are coke oven gas and tar. The following block diagram represents material balance: coal of certain composition is charged and coke, coke oven gas and tar of certain composition is produced

Coal (wt %)  
C  
H  
O  
N  
S  
Ash(A2)  
M

Coke  
(analysis, wt%)  
Tar  
(analysis, wt%)  
Coke oven  
gas(vol%)  
C  
H  
O  
N  
S  
Ash (A2)  
Ash (A3)

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

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

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

By knowing weight of tar, W can be calculated.

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

C from coal = C in coke + C in tar + C in coke oven gas

In the present illustration, if Y Kg mole is the amount of producer gas
Heat Balance:
For heat balance calculations, reference temperature of 298K is normally selected.

Heat balance at steady state is

\[ \text{Heat Input} = \text{Heat output} + \text{Heat losses} \]

In coke-making heat input is the calorific value of coal and CV of coke-oven gas burnt. CV of coal can be determined by Dulong formula as illustrated in Lecture 2.

Heat output consists of

(i) Sensible heat in coke:
It can be determined by
\[ W \times C_p \times (T_{\text{coke}} - 298) \] in Kcal or KJ,
where X is mass of coke, \( C_p \) is specific heat of coke and \( T_{\text{coke}} \) is temperature of coke discharged from coke oven. \( C_p \) is 0.359 Kcal/Kg\(^\circ\)C.

(ii) Sensible heat in coke oven gas:
It may be calculated by
\[ Y \times C_{pg} \times (T_{g} - 298) \] in Kcal or KJ,
where \( C_{pg} \) is specific heat of coke-oven gas. Its value may be taken as 0.44 Kcal/m\(^3\) \( \circ\)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 in Lecture 2.

Heat balance calculations can 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.

Next lecture illustrates material balance calculations. The reader must revise the concept of calorific value and must also practice to calculate calorific value of solid and gaseous fuels

References:
O.P.Gupta: elements of fuels, furnaces and refractories

Key words: Coke making, coke oven, blast furnace