Module 1: Fundamental definitions, properties and various measurements

Lecture 4: Definitions and properties of solid fuels

***Keywords*: property, analytical methods, coal carbonization, caking, swelling**

1.3.1 Definitions and properties of solid fuels

Coal varies widely in composition and properties and they are used in different conditions. Coal characteristics are determined by various kinds of analytical and testing data, which are of scientific, technical and commercial interest. Following are the definitions of some coal characterization and analysis.

Ultimate and Proximate analysis of coal

Ultimate analysis is the elemental analysis which determines the percentage composition of carbon, hydrogen, oxygen, nitrogen and sulfur by weight. These elemental compositions are of pure fuel only, which is free of moisture and inorganic compounds.

Proximate analysis reports moisture, volatile matter, ash and fixed carbon content of a fuel by percentage weight, as defined by ASTM D 121. Moisture is the amount of water obtained from the fuel by heating at a specific condition according to the standard method, without making any chemical change to the fuel. Volatile matter consists of gases and vapors driven off during pyrolysis under specified condition minus moisture, fixed carbon is the nonvolatile fraction of coal, and ash is the inorganic residue remaining after combustion. Proximate analysis is the most often used analysis for characterization of coals.

Gross and Net calorific value

When coal is heated at high temperature in presence of air, heat liberated per unit weight of fuel is called heating value or calorific value of that fuel. Calorific value can be determined either at constant volume or constant pressure. Gross calorific value at constant volume is the amount of heat liberated by combusting unit weight of coal at constant volume in an atmosphere of water

vapour saturated oxygen, the original fuel and final products of combustion should be at 25^0C and the water obtained by this process should be in liquid state.

Gross calorific value at constant pressure is similar to that of constant volume, only difference is that, the combustion occurs at constant pressure.

Net calorific value at constant volume is the amount of heat liberated by combusting unit weight of coal at constant volume in an atmosphere of water vapour saturated oxygen, the original fuel and final products of combustion should be at 25^0C and the water obtained by this process should be in vapour state. Net calorific value at constant pressure is that, the combustion occurs at constant pressure, not constant volume.

Gross calorific value is also called higher heating value as it is higher than net calorific value. The reason for this is, while determining net calorific value, the water remains in vapour state, hence the heat of condensation is not taken in consideration, which is rather a part of gross calorific value where water obtained is in liquid phase.

Ash content

Ash in coal, which is the remains when coal is burnt, is one of the materials of interest. Ash is derived from the mineral matter content of coal. The inorganic materials which were actually the part of the plant structures, constitute the 'inherent' mineral matter of coal, whereas, the 'extraneous' mineral matter is that which was introduced probably as air-borne dusts or water-borne silts at the later stage of coalification. Mineral matter of coal predominantly consists of kaolinite, pyrite and calcite and upon combustion; results in the oxides of silicons and metals, such as, aluminium, iron and calcium. These oxides are the essential part of ash. When coal burns, shales and other hydrated materials, which are also the constituents of mineral matter of

coal, decompose and lose their water of hydration and also emit carbon dioxide, sulfur dioxide gases. As there is a loss in weight, so, amount of ash of coal is always less than its mineral matter content.

Moisture content

Moisture of coal may also become inherent or extraneous. Inherent moisture is the moisture associated with coal inherently, which cannot be removed by only air drying, it can be removed when coal is heated above 100^0C. Extraneous moisture can be removed by air drying of coal.

Volatile matter

Volatile matter is the volatile part of coal when coal undergoes thermal decomposition. The volatile part of organic mass of coal is the main constituent of it. The moisture content of coal is not included in it. But volatile matter of may contain water, when hydrogen and oxygen of coal produce water at high temperature of decomposition. The water of hydration, which is liberated during decomposition, is also a part of volatile matter. It is observed that, as the maturity of coal increases, volatile matter decreases. Fixed carbon is the non volatile part of organic mass after decomposition. Ash is not included in it. Fixed carbon should not be confused with the total carbon of coal. In anthracite, the values of fixed carbon and total carbon are almost equal, whereas, for other coals, fixed carbon is less than total carbon.

The major elements present in coal are carbon, hydrogen, oxygen, sulfur and phosphorous. There are different methods to determine their content.

Coal carbonization, caking index and swelling index

Coal carbonization is the process where coal is heated at high temperature without contact of air. The decomposition product is of higher carbon content than the original coal. When coal is converted to gaseous fuel by heating at sufficiently high temperature, the process is called gasification of coal. During carbonization, some gaseous products are also produced.

During carbonization, some types of coal can produce lumps from its pulverized form. These lumps are called cake and the process of cake formation is called caking. When these lumps can meet the specification of some standard tests in terms of its hardness, brittleness etc. and also its suitability to use in steel industry as a source of heat as well as a reducing agent, then they are called coke. Coke is prepared in commercial coke oven by the process of carbonization at more than 1000^0C. This carbonization process is called coking.

All types of coal do not show caking property. Some types of bituminous coals are caking in nature. Other coals are non-caking. Hence, caking property of a coal is important for selection of a particular type of coal in industrial purpose. Caking index is determined for coal to obtain its binding or agglutinating property. This is defined as the maximum whole number ratio of sand to coal in a 25 g mixture of those two, lumps produced by heating that mixture at a specified condition which can withstand a 500 g weight, and the loose particles obtained by this process should not exceed 5%.

Swelling index is another important property of coal, where it is heated under specified condition. The residue obtained is a swollen mass due to volatiles in coal are driven off. This mass is compared with a standard chart where pictures of different swollen mass are given with a definite number or unit, starting from 0 to 9, with an increment of ½. The number of the picture with which the swollen mass matches is its swelling index.