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Characteristics of Coal and Coal Ash

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Abstract

The physical character or composition of coal in the form of deposits used as trading materials are different. This is due to conditions, including peat formation, change in geological time, and methods or process of mining. The characteristics of coal, including water (moisture), volatile matter, porosity, density, grind ability, friability, weathering, size composition, Strength, and abrasiveness, determine the use. Furthermore, Ash is a residue obtained from the mineral matter due to changes in coal. The chemical composition is different with less weight than the mineral matter present in the original form. Also, the change in mass recorded during this entire process is attributed to water loss from the original silicate, CO_2, and oxide from carbonate and pyrite oxide, respectively. However, the main components of ash elements include Sodium, Calcium, Magnesium, Potassium, Aluminum, Silicon, Iron, and Sulfur.

Keyword: Coal, Characteristics of coal, Ash

I. INTRODUCTION

The physical characteristics or composition of coal in the form of deposits used as trading materials are different. This is due to some conditions, including peat formation, change in geological time, the methods, or process of mining. These characteristics are improved by washing and processing before the coal is utilized. Furthermore, some of these improvements are to produce a more uniform product, optimize size distribution and moisture content, as well as reduce the mineral amount. The coal ash content is obtained from the mineral matter at the time of formation. Also, as the coal is burned, residue from the combustion is termed, Ash. The ash content in coal is mineral matter. This mineral matter consists of two materials, namely inherent mineral matter, and extraneous mineral matter. Inherent mineral matter is formed along with the formation of coal during the coal process and is an integral part of the coal substance. The amount is about 0.5-1.0% of coal, and because of this formation, the inherent mineral matter is difficult to separate in the process of removing impurities. Extraneous mineral matter is derived from other material, which is mixed into the coal via cracks or cleavage during coal formation. Usually, this extraneous mineral is in the form of slate, shale, sandstone, clay, or limestone, and the amount can be in microscopic size to thick layer and bands. A run of mine can contain extraneous mineral matter, which comes from impurities when mining coal activity at a coal roof or floor. Depending on the formation, the extraneous mineral matter can be removed by coal washing. During the screening process, fine extraneous mineral matter such as sand and clay can be removed. The main component that forms coal consist of water, mineral matter, and pure coal. Mineral matter when coal burns completely, what remains is in the form of residue or Ash.

II. RESEARCH METHODOLOGY

The analysis method used to determine the characteristic and Ash of coal are XRD and proximate.

II.1. Analysis of XRD (*X-Ray Diffraction)*

This method has been used extensively, identifying minerals in coal (Finkelman et al., 1981). To obtain an optimum result, the coal sample is prepared to fine size -250 *mesh*. The organic and inorganic components can be separated by low ash temperature. The organic components will be oxidized in order to only the mineral components remain, and the residue is then analyzed using a diffract meter. The resulting diffractogram is then interpreted using a table of Hanawalt and *X-ray Powder Data File* (PDF).

II.2. Analysis proximate

The analysis was conducted on coal samples to determine the coal quality parameters. The analysis of proximate consist of ash content (ASTM D 3173-73, 1994), inherent moisture (IM) (ASTM D 3174-73, 1994), volatile matter content (VM) (ASTM D 3177-73, 1994) and fixed carbon (FC).

III. LITERATURE REVIEW AND DISCUSSION

III.1. Characteristics of Coal

The possible use of coal is affected by some of the following characteristics (Thomas, 2002):

III.1.1. Water (moisture)

Water in coal is discovered within:

- The surface and cracks termed free water (*free moisture*) or surface water (*surface moisture*).
- The capillary cavities termed *inherent moisture*.
- The crystals of mineral particles present in coal termed hydrated water.
- The organic part of coal termed decomposition water.
- The surface and inherent moisture have normal and low vapor pressure, respectively.

In comparison to ordinary water. Furthermore, hydrated water is generally seen in clay materials and is part of the crystal *lattice*. This liquid is liberated at a temperature of 500^o C, while decomposition water is released from 200^o - 250^o C. However, moisture is not included in the analysis of ordinary coal-water because the study uses temperatures far below 200^o C.
Furthermore, total water, also known as *-received moisture*, is the amount of surface and inherent moisture from the coal at the time of analysis. The *Air-dried* moisture is the escaped liquid after drying in the open air. Moreover, there are several disagreements about the meaning of water in coal.

III.1.2. Volatile Matter
Also, heating coal in an inert atmosphere to a temperature of 95^0 C produces a material termed a flying substance. This consists of a gas mixture with low boiling organic compounds inclined to melt and further produce material in the form of oil and tar. The process is termed pyrolysis, meaning to separate using heat (Speight, 1994, 2005).
The flying substance is very important due to the usage as a parameter in the classification and evaluation of coal for combustion, carbonization (making coke), gasification, and liquefaction.

III.1.3. Porosity
Furthermore, coal contains two pore systems, including the average size orifice of 500 A^o and the small variant of 5 - 15 A^o ($1A^o$ = 10-10 m). The number of small pores is lesser, while the surface area is larger (approx. 200 m^2 / gr) in comparison to the large pores with a total of 1 m^2 / gr. These orifices absorb formed methane in the final stages of the coal formation.

III.1.4. Density
There are several types of density measurements, depending on the intended use, including *Bulk density*: This is the weight per unit volume of loose coal used to calculate the amount of *stockpile*, bin, and also utilized in fuel storage with a certain weight.
- *Apparent density*: This is a measure for coal lump, including *inherent moisture*, mineral matter, and air in the pores.
- *True density*: This represents coal free from air and bound water but includes *mineral matter*.

III.1.5.Grindability and Friability
- *Grindability*

Hardgrave Grindability Index (HGI) is a measure of coal's resistance to pulverization, and this property has a standard value of 100. Therefore, a lower figure implies easier crushing. Also, HGI is named after *Hardgrove Ralph,* the inventor of this test.
Medium and *low volatile* coals are classified as easily crushed. Meanwhile, those of the high volatile bituminous and anthracite category are tougher. This property increases with a rise in carbon content up to 90% and then declines.
- *Friability*

This describes a material's ability to resist crumbling under pressure or contact. Furthermore, the grindability and friability of these solids depend on toughness, elasticity, and fracture.
In addition, this property is significant with regard to the new surface area created during coal handling, as this accelerates oxidation, spontaneous ignition, loss of coking quality, and other subsequent changes.
Friability rises with an increment in carbon content until 75% and decreases from this point (anthracite) (Osborne, 1998).

III.1.6. Weathering
Weathering is defined as the tendency for dry coal to break. These symptoms are known to manifest while the mineral is in contact with the atmosphere. For instance, spontaneous combustion tends to occur each time heat released from oxidation is greater than the convection or conduction counterpart.

III.1.7. Size composition
This is an important aspect of the determination of the coal market price. Furthermore, ash and sulfur contents, as well as heat value, are factors influencing quality. These characteristics are generally associated with the size of components and are often denoted in contracts as a percentage.

III.1.8. Strength
The Strength of coal is concerned with the development, crushing Strength plus the *mode of failure*, and depends on the rank, conditions, as well as the stress methods, applied. Meanwhile, Strength is studied by means of a compression test because the results obtained are applicable in the estimation of the load capacity of mine pillars.

III.1.9. Abrasiveness
This property is paramount in terms of mining economics, preparation, and use. In addition, coal is an abrasive material; hence, the mining equipment and conveyances tend to wear significantly and are expected to be replaced frequently. Furthermore, these damages have also been implicated in increasing costs.

According to a previous study, abrasiveness varies in coal as a result of the mineral's heterogeneous nature. The *Seattle Coal Research Laboratory of USBM* has developed a technique to measure this property by using a tool consisting of 4 iron blades rotating in a coal filled compartment. After a fixed number of turns, the weight losses from these sharp edges are determined.

The results indicate abrasiveness is influenced by the type and number of impurities in coal. Therefore, washing aimed at reducing impurities will, in turn, reduce *abrasiveness*.

III.2.Ash of Coal

Ash is a mineral residue resulting from combustion. This substance possesses a different chemical composition and lesser weight than the inorganic component of the original coal. In addition, there is a change in weight due to dehydration of silicate, CO_2 as well as sulfur loss from carbonate and pyrite oxide, respectively, during formation. The major elemental constituents of ash elements include Sodium, Calcium, Magnesium, Potassium, Aluminum, Silicon, Iron, and Sulfur.

Coal ash is utilized in *power stations* as a result of the melting nature. Therefore, there is a need to understand this minerals' behavior at high temperatures to determine the suitability for use in various furnaces. This is carried out through an *ash fusion test*, where the Ash shaped into a three-sided pyramid and heated between 900-1600^{0}C in a reduction atmosphere. Subsequently, the sample was transformed into *original, spherical*, *hemispherical,* and *liquid*.

This temperature change symbolized the best reference to determine the performance of Ash in the furnace. Therefore, three vital points were defined in the *reducing atmosphere*:
- Initial deformation temperature, referring to instances where the sample acquires around or bend appearance at the *apex pyramid*.
- Softening temperature, the stage where the sample had melted to form a round pile.
- Melting temperature, where the molten specimen commenced dispersion into a thin layer.
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Ash Fusion Temperature (ATF) was measured with regard to two parameters, namely oxidation, and reduction. Estimations under oxidative environments revealed a greater value relative to the presence of some ash components such as iron oxide. The compound displayed a distinct fluxing effect, referring to properties exhibited as a flux or added material, varying during oxidation or reduction. For instance, the effect of iron content on the initial deformation temperature (ISO-A) of Ash under two different circumstances. *Ash Fusion Temperature*, irrespective of oxidative or reductive states, is reliant on the type of coal utilization operation. An instance is observed in gas manufacturing industries where the reducing state occurs in the fuel bed, and therefore, the AFT is estimated at this phase. Conversely, the *fixed bed furnace* base exhibits oxidizing conditions. Hence, the value determines the circumstances. Furthermore, the properties of pulverized fuel combustion are not certain, as reduction occurs in the flame, while oxidation is the foremost condition outside the flame, depending on the amount of supplied air.

Ash Fusion Temperature is affected by the following ash conditions (Krevelen, 1992):

a. Al_2 O_3/SiO_3, with a ratio of 1: 1.18, has a high flow temperature, alongside a narrow (dwarf) melting temperature range.
b. Cao, MgO, and Fe_2O_3 function as flux and promote a decline in value, especially on instances where SiO_2 is in excess.
c. FeO, Na_2O, and K_2O possess high capacities for AFT reduction.
d. High sulfur content also diminishes the initial deformation temperature and expands the melting point scale.
   Consequently, the resulting data is applied to the differentiation between slagging and non-slagging coal. Therefore, a softening temperature below 1250^0C describes slagging coal, and optimal performance is observed in furnaces where ashes are extricated as slag.

Meanwhile, a temperature above 1450^0C defines non-slagging coal, and the resultant lash deters softening in most industrial incinerators. However, the formation of slag by materials with melting temperatures between 1250^0C-1450^0C is uncertain. Therefore, the furnaces to be utilized for this type of coal are to be constructed to prevent the formation of ash melt or to facilitate the retention in the softened form.

IV. CONCLUSION

The characteristics of coal affect its utilization, and these include water (moisture), volatile matter, porosity, density, friability, alongside the ability to be pulverized, as well as weathering, size composition, Strength, and abrasiveness.

The chemical composition of Ash is distinct and weighs less than the mineral matter present in the original coal. The main components, therefore, include Sodium, Calcium, Magnesium, Potassium, Aluminum, Silicon, Iron, and Sulfur. The Ash in coal comes from mineral matter and is the residue of coal combustion.

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