Journal of Multidisciplinary Engineering Science Studies (JMESS)
ISSN: 2458-925X
Vol. 3 Issue 6, June - 2017

# Bridging Nigeria Energy Gap by Utilizing her Coal

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***Abstract* – Many nations who meet their energy generation requirements are one way or the other tapping from the vast resources which is inherent in coal.**

**A wide gap exists between the energy requirement of the Nigerian populace and the generated amount. This can be bridged by the utilization of its vast amount of bituminous coal in her reserves, with favourable properties of low percentage moisture and ash which is an advantage in terms of handling costs, ease of transportation and better overall system efficiency.**

**The percentage moisture value for the analyzed sample was 5.0 percent while the percentage ash value was 6.6 percent. Both determined values are relatively low when compared to results of the analysis reported for some other countries coal**

***Keywords—Ash content, Bituminous coal, Coal, Energy, Moisture content, Proximate analysis***

## I. INTRODUCTION

In many nations' quest to meet its ever increasing energy demand, coal has come to the forefront. Coal's contribution to the energy supply of the United States of America in 2013 was about 92%, and in the year 2016 about 30.4% of its electricity generation was based on coal. India as a country have an installed electricity generation capacity of about 250GW and about 140GW of this value is derivable from coal; contributing approximately 1.5% of the country gross domestic product.

South Africa's dependency on coal for meeting of her energy requirement cannot also be overstated, estimates show that about 77% of its energy needs are met by the utilization of coal, while also providing about 43% of her electricity generation.

The wide gap between the electricity needed to drive the economy and the generated/available electricity to the Nigerian populace is very alarming, necessitating the need to take a clue from other nations who are tapping the inherent energy in coal to meeting their electricity needs. Nigeria is also richly blessed with coal deposits.

Two basic parameters, moisture and ash content, which to a great extent significantly determines the cost effectiveness and technology of the utilization of coal for electricity generation is investigated in this study.

The presence of moisture is an important factor in both the storage and the utilization of coals, as it adds unnecessary weight during transportation, reduces the calorific value and contributes to its handling problems.

The total moisture content of coal is the percentage of water in all forms (except water of crystallization of the mineral matter) that resides within the coal matrix.

From economic point of view, the combustion of coal with low moisture content is more desirable than using a moist one, thereby making the moisture contents an important property to be considered in coal utilization.

The ash content in coal is another important parameter. Ash reduces the calorific value of coals. Ash is technically the solid residual end product of combustion of coal and is realized only on combustion since it is an integral part of the overall coal lump.

The combustion of coal is affected by the quantity of ash in it, as it does interfere with the process, and affects the thermal efficiency of the steam plant. High ash content in coal will also result into increased cost for coal cleaning.

## II. LITERATURE REVIEW

The estimated value of Coal deposits in the Nigeria's reserves based on data from the ministry of solid minerals development stands at 2.75 billion tonnes, out of which 0.639 billion tonnes have be proven [1]. The prospects of proving more quantities in the reserves are very bright if the required attention needed in the sector is focused on it.

Calorific value of coal is the amount of chemical energy stored in it which is released as thermal energy upon combustion and it is directly related to its rank. The calorific value determines in part the value of a coal as a fuel for combustion applications. Nigerian coal deposits is basically bituminous in nature, and from the studies carried out by Towoju [2] showed that it's Higher and Lower calorific value (HCV and LCV) are 34,710.34KJ/kg and 33,357.01KJ/kg respectively, which when compared with that quoted in text by Eastop and mcConkey [3] (HCV = 33,500KJ/kg and LCV = 32,450KJ/kg) connotes a better rank of coal.

Moisture and ash are the main non-chemically reactive ingredients in coal which result into a drop of its gross calorific value. Moisture in coal consists of inherent moisture (IM) and surface moisture (SM). The total moisture (TM) is a sum of the IM and SM. The gross calorific value of coal is reduced by the presence of moisture, meaning a reduction in the output it delivers, reduced boiler efficiency and unit overall efficiency. This is asides the difficulty it pose on transportation: movement in conveyors, chutes, hoppers, bunkers and pipes, and grinding, milling and flow ability [4][5]

The levels of moisture in coal have been shown to have a direct effect on the emission of Nitrogen oxides (NOx) during its combustion even as this level also significantly enhances the uptake of solvents. There is a strong analogy with enhancement by water of diffusive transport in hydrophilic polymers. Flame temperature and NOx mole fraction decrease with increasing moisture because the fraction of the unburned carbon increases, while the Oxygen mole fraction increases in the region near the burner, and the peaks of the flame temperature and NOx mole fraction shift downstream. [6][7] Typical percentage by weight of moisture in bituminous coal falls within the range of (2.2 – 15.9) % and (2.8 – 16.3) % in Anthracite.

In order to fully optimize the use of coal, laser induced breakdown spectroscopy (LIBS) have been developed for its fast analysis. However, the moisture content of coal has also shown to have a great influence on its analytical performance, even as it has been stated that the process of heat treatment of coal in relieving it of its moisture can significantly affect its cross-link density and its subsequent solvent intake. [7][8]

Coal combustion involves a number of complex exothermic reactions which controls it's self-heating. Self-heating is dependent on its moisture content. It will continue to self-heat provided there is a continuous supply of Oxygen and the heat generated is not dissipated. [9]

The level of ash in coal has an indirect effect on its combustion; high percentage of ash in coal makes it a necessity to use a higher amount of primary air than required for actual combustion, because the transportation velocity requirement limits the minimum primary air [10]

Ash is a noncombustible residue left over after the combustion of coal. It is an indicator of the quality of coal. It is represented as a percentage of the original weight.

Ash is an impurity that will not burn, and its typical range in coal is from (5 to 40) %. It reduces handling and burning capacity, affects combustion efficiency and boiler efficiency, causes clinkering and slagging and increases handling costs. [5]

As the ash content increases from 6% to 75%, different effects are noticed on the generation system; total boiler area requirement increases, boiler efficiency drops, specific energy consumption increases for mills and primary air fans, specific fuel consumption increases and the gross and net overall efficiencies are reduced.

When the ash content of coal goes beyond 57%, limitations in combustion space and flow arise, and beyond this value the unit has to be operated only at partial load. [11]

Table I below shows the proximate analysis results for various coals as documented in coal analysis.pdf. [12], while Table II gives the analyses of coal samples taken from Indiana and Powder River basin coal. [13]

TABLE I. TYPICAL PROXIMATE ANALYSIS OF VARIOUS COALS (IN PERCENTAGE)

| Parameter | Indian Coal | Indonesian Coal | South African Coal |
|---|---|---|---|
| ***Moisture*** | 5.98 | 9.43 | 8.5 |
| ***Ash*** | 38.63 | 13.99 | 17 |
| ***Volatile matter*** | 20.70 | 29.79 | 23.28 |
| ***Fixed Carbon*** | 34.69 | 46.79 | 51.22 |

*Sourced from Coal analysis.pdf*

TABLE II. INDIANA AND POWDER RIVER BASIN COAL

| Parameter | Indiana Coal | Powder river basin coal |
|---|---|---|
| ***Moisture*** | (10 – 12) % | ~28% |
| ***Volatile matter*** | ~40% | higher |
| ***Heating value*** | 11,386 Btu/lb | 8,088 Btu/lb |
| ***Ash content*** | 9.4% | 7.6% |
| ***AFT (flow, reduction)*** | Need more data | ? |
| ***Slag viscosity~ 1400$^0$C*** | Need more data | ? |
| ***Char reactivity*** | Very few data Less reactive (higher T needed?) | More reactive because of more volatiles? |
| ***Sulfur*** | 3.13% | 0.72% |
| ***Chlorine*** | 0.05% | 0.01% |

*Sourced from Indiana Geological Survey, Indiana University, June 2005*

## III. METHODOLOGY

The importance of the effect of moisture content and ash in the optimum utilization of coal for energy generation and as a raw material cannot be overemphasized. Nigeria's sub-bituminous coal which is the common type of its existence in the country is analyzed experimentally for moisture and ash. The coal sample was collected from Enugu mines in the south eastern part of Country.

### A. Moisture content determination

The following apparatus were utilized in the determination of the moisture content of the sample; conventional frying oven, desiccators, weighing/drying dishes and an analytical balance with accuracy up to 0.1mg.

The sample was accurately weighed into an uncovered pre weighed clean weighing/drying dish using the analytical balance. This was then placed in a well ventilated oven which was maintained at 105$^0$C for about sixteen (16) hours. The dish containing the sample was then covered with a lid and transferred to a

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ISSN: 2458-925X
Vol. 3 Issue 6, June - 2017

desiccator where it was allowed to cool to room temperature, after which the dish with the content was weighed and the readings recorded.

The drying/weighing dish was afterwards placed back in the well ventilated oven for two (2) hours, cooled in the desiccator and re-weighed. This procedure was repeated until the difference in weigh readings between successive weighing was found to be negligible.

The moisture content was then computed using the relation;

$$(\text{Moisture weight} = \text{Initial weight of sample and dish} - \text{final weight of sample and dish}) \quad 1$$

$$\text{And } \%\, moisture = \frac{\text{moisture weight} * 100\%}{\text{Sample weight}} \quad 2$$

B. Ash content determination

The apparatus utilized in the determination of the ash content are as follows; muffle furnace, porcelain crucible, desiccators, hot plate, fume cupboard and analytical weigh.

The crucible was first dried in an oven and allowed to cool in a desiccator, before it was weighed and the readings recorded. About two (2) grams of the sample was placed in the weighed crucible and ignited on the hot plate placed inside a fume cupboard to exclude the organic matters. The crucible with the content was later placed in the muffle furnace maintained at a temperature of 600$^0$C for eight (8) hours after which the crucible was transferred to the desiccator where it was allowed to cool and later weighed accordingly.

The ash content was then computed using the following relations;

$$\%\,\text{Ash} = \frac{[(\text{weight of crucible+ash}) - (\text{weight of empty crucible})] * 100\%}{\text{Sample weight}} \quad 3$$

## IV. Results and Discussion

The moisture content and ash of the sample were determined using proximate analyses. Table III and Table IV give the results for moisture content and ash for the coal sample.

The moisture percentage was gotten using the relation in equation 2, while the ash percentage was determined using the relation in equation 3.

The moisture content of the analyzed coal sample was gotten to be 5.01% which in comparison with Indian, Indonesian and South African coal as depicted in Table I is lower [12], also the same is the case with Indiana and Powder River basin coal as depicted in Table II [13] making it to be of better quality in meeting of transportation and handling requirements, and more importantly it will have a better overall unit efficiency. [4]

The percentages of ash in the referenced coal samples were found to be higher than that of the analyzed Nigerian coal; The Powder River basin sample with the lowest ash content (7.6%) [13] is even greater than that of the analyzed Nigerian sample (6.62%). As stated in the works of Pankaj [5] the presence of ash reduces handling and burning capacity, affects combustion efficiency and boiler efficiency. The Nigerian coal will thus have a better burning capacity, combustion and boiler efficiency, and will be much easier to handle in comparison to the analyzed samples of India, Indonesia, South Africa, Indiana and Powder River basin.

TABLE III. Moisture Percentage

| Sample weight (g) | Dish + sample weight (g) | Dish + dry sample weight (g) | Moisture weight (g) | % |
|---|---|---|---|---|
| 3.0752 | 34.7746 | 34.6203 | 0.1543 | 5.01 |

TABLE IV. Ash Percentage

| Sample weight (g) | Crucible + sample weight (g) | Crucible + ash weight (g) | Ash weight (g) | % |
|---|---|---|---|---|
| 2.0299 | 12.3097 | 10.4142 | 0.1344 | 6.62 |

## V. Conclusion

The Nigerian bituminous coal has properties which are required for its utilization as an energy generator in bridging the gap between most especially the electric power required by the country for her industrialization and that which is now being generated.

The results from this study showed that the Nigerian bituminous coal has relatively low percentage value of moisture and ash in comparison with some other countries coal, making it a better potential source for use in electric power generation

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