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Gray-King Assay Characterisation of Nigerian Enugu and Polish Bellview Coals for Co-carbonisation

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Abstract: The Nigerian Enugu and Polish Bellview coals were subjected to proximate analysis and Gray-King coke assay type tests. Proximate analysis gave the ash content as 7.57 and 5.56%, the volatile content as 51.76 and 31.06%, respectively for Enugu and Bellview coals. For the Gray-King coke type assay test, the coke types of B and G, the percentage coke yield of 71.70 and 80.40% and percentage tar yield of 23.30 and 11.40%, respectively, were determined for Enugu and Bellview coals. The coke type, the ash content and percentage coke yield confirms Bellview coal as a medium coking coal, suitable for cokemaking but with a volatile content that exceeds the upper limit of 30.3% for cokemaking at Ajaokuta and Enugu coal as a high volatile non-caking coal. However, the higher yield of tar from Enugu coal may be an advantage in its use as a binder in producing formed coke.

Key words: Coal, Gray-King, ash, tar, cokemaking

INTRODUCTION

Coals are organic detrital sedimentary rocks that originate from a variety of plant material and different tissues deposited in more or less aquatic locations (Loison *et al*., 1989). Coal vary in rank depending on the degree of maturity attained during metamorphism. A coal is characterized by a number of chemical, physical, physico-chemical and petrographic properties.

In proximate analysis of coals, moisture, ash, volatile matter and fixed carbon contents are determined under strictly standardized conditions. It is the simplest means of characterizing coals for utilization. Water exists in coal either as free surface water, surface adsorbed, capillary condensed water and water bound to the coal molecule by chemisorptions or hydrogen bonding with the reactive groups. The free surface water evaporates out of coal when it is kept exposed to the atmosphere, while the other forms of water are retained in coal depending on the atmospheric humidity. They are released only at high or temperatures. The determination of moisture content is important not only to assess the commercial value of coal but also because of its relationship to other properties (Moitra *et al*., 1972). Ash in coals are due to mineral matter which are either co-deposited with the coal-forming vegetable matter or gets into coal by subsequent infiltration. On incineration of coal, the organic matter burns off leaving the product of oxidation of the mineral matter. The ash in coking blends should be as low as possible.

The volatile products obtained during the pyrolysis of coal under specified conditions are known as volatile matter. It consists mainly of hydrogen, methane, carbon monoxide, carbon dioxide, hydrocarbon, tar, water vapours, nitrogen, ammonia, hydrogen sulphide etc. It is mainly derived from the peripheral groups of the coal molecule up to a pyrolysis temperature of 600 to 700°C. Immature coals have higher weights of these peripheral groups and thus their volatiles are more than for mature coals in which these groups are fewer. The yield of volatiles is therefore an approximate measure of rank (Moitra *et al*., 1972).

When bituminous coals are heated, they develop plastic properties at about 350°C and as a result exhibit fluidity, swelling, agglutinating properties, expansion and contraction in volume and after carbonization produce coherent residues of varying strengths depending on the rank of the coals. Gray-King coke assay test is one of the tests developed to measure this physico-chemical characteristic of coals (Moitra *et al*., 1972).

The efforts to source coals for cokemaking at the Nigerian Ajaokuta integrated Steel Plant, led to location of coal deposits with proven reserves of 54, 74 and 22 million tons at Enugu, Okaba and Lafia, respectively. Of these

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three deposits, only Lafia coal is medium coking but with intolerable ash and sulphur contents of 22.91 and 1.90%, respectively. The non-caking Enugu and Okaba coals however contain acceptable levels of ash and sulphur (Anonymous, 1987). The Bellview coal was imported from Poland to produce cokeable blends with Nigerian coals. In this research, Bellview and Enugu coals were subjected to Gray-King assay tests to study their blendability for cokemaking and tar yielding capacity.

Assay analysis was a key parameter determined in the study to utilize the Canadian Hat Creek coal. The tar yield of the coal was determined as 6. 8% (http://www.em.gov.bc). The current international market price of US$300 per ton for coal makes research in the area of co-carbonization of coking coals with sub-bituminous coals more urgent (http://www.englishpeople.com.cn).

MATERIALS AND METHODS

Materials: Samples of Enugu and Poland's Bellview coals were used for the Gray-King assay tests. The Bellview coal was imported from Poland for the Ajaokuta steel plant, while the Enugu coal was obtained from Enugu coal mines in Nigeria.

Methods: The tests were conducted in the Fuels and Energy Laboratory of the National Metallurgical Development Centre, Jos, Nigeria. Coal samples pulverized to pass 250 micron were used for both proximate analysis and Gray-King assay tests.

Proximate analysis (NMDC manual, 1994): Proximate analysis involves determination for moisture, ash, volatile matter and fixed carbon.

Moisture: The silica crucible for the test was preheated at 105°C for 1 h. One gram of coal sample was then placed in the crucible and heated at 105°C for 1 h. The loss in weight accounts for the moisture content.

Volatile matter: The standard crucible was preheated in the muffle furnace at 970°C for 7 min. The crucible was cooled in the desiccators and 1 g coal sample was placed in it with three drops of benzene. The crucible (with the lid on) was now placed in the muffle furnace at 970°C for 7 min. The loss in weight accounts for the volatile content of the coal.

Ash: The standard silica crucible was preheated at 825°C for 1 h. It was the cooled in the desiccators. One gram of coal sample was placed in the crucible (with the lid on) and it was heated at 825°C for 1 h. The incombustible residue gives the ash content of the coal.

Fixed carbon: The fixed carbon is obtained from the relation:

$$\text{Fixed carbon\%} = 100 - \text{moisture\%} - \text{ash\%} - \text{volatile matter\%} \quad (1)$$

Proximate analysis results are presented in Table 1.

Gray-King assay test: Five gram of coal was placed in a silica retort, 300 mm long and 19 mm internal diameter. One end of the retort is round and closed and at the other end, a side arm is fused which serves as an exit for the tarry vapours and gases released during the experiment. With the retort held horizontally, the coal was spread over the length in an even layer. The retort was then introduced horizontally into the tube furnace maintained at 325°C. The furnace temperature was raised at the rate of 5°C per minute till a temperature of 600°C was attained. The furnace was maintained at this temperature for 15 min. The retort was then taken out, allowed to cool and the coke pencil produced was brought out. It was now compared with the standard profiles which are designated A, B, C, D, E, F, G, G1, G2, ..., G9 (Moitra *et al*., 1972). The results of Gray-King Assay tests are presented in Table 2.

The percentage coke and tar yield are calculated as follows:

$$\%\ \text{coke yield} = \frac{a}{W_s} \times 100 \quad (2)$$

$$\%\ \text{tar yield} = \frac{b}{W_s} \times 100 \quad (3)$$

Where

a = Weight of semi-coke residue in the test tube
b = Weight of tar and water collected
Ws = Weight of sample

Table 1: Result of proximate analysis

Parameters (%)	Enugu coal	Bellview coal
Moisture	8.15	0.57
Ash (ad)	7.57	5.56
Ash (db)	8.24	5.59
Volatile matter (ad)	43.62	29.16
Volatile matter (db)	47.50	29.33
Volatile matter (daf)	51.76	31.06
Fixed carbon (db)	44.27	65.07
Fixed carbon (daf)	48.24	69.00

Ad-as determined, db- dried basis, daf- dried ash free

Table 2: Gray-King assay test parameters

Parameters	Enugu coal	Bellview coal
Weight of empty test tube for coal (g)	78.27	88.90
Weight of test tube + coke (g)	85.44	92.92
Weight of test tube for tar (g)	51.42	77.02
Weight of tar + water (g) + test tube	53.80	77.59
Percentage coke yield	71.70	80.40
Percentage tar yield	23.80	11.40
Gray-King coke type	B	G

The Gray-King coke type results has been reported not to be susceptible to weight of samples, but to such other factors as the state of oxidation and size of the coal samples (Moitra *et al*., 1972).

DISCUSSION

The moisture content of 8.15 and 0.57% determined for Enugu and Bellview coals respectively falls within the range required for coals to be carbonized for metallurgical cokemaking at Ajaokuta (Federal Ministry of Mines, Power and Steel (FMPS) circular, 1992). The moisture contents for the two coals are also lower than the 12.80% determined for the low rank Australian Loy Yang coal (Xiaofeng *et al*., 1998). However, Enugu coal moisture far exceeds the 1.5-2.2% for the Indian Jharia coal samples (Moitra *et al*.,1972; Prasad *et al*., 1992). On the basis of their moisture contents, the two coals can be considered suitable for inclusion in blends for cokemaking.

The ash content of 7.57 and 5.56% for Enugu and Bellview respectively are far lower than 20 to 25% for Indian Jharia coal samples and 17.52% for Indian prime coking coals (Prasad *et al*., 1992). The ash for the two coals also satisfy the 10% upper limit for coals to be carbonized at Ajaokuta (Federal Ministry of Mines, Power and steel circular, 1992). The ash content of Lafia coal, 15.9%, determined by Afonja (1996) also exceeds those of Enugu and Bellview coals. The ash contents of the two coals fall within the 7.2 to 9.6% range for main coals carbonized in Japan to produce coke (Katsuhiko *et al*., 1987). The tolerable ash contents of the imported Bellview and Nigerian Enugu coals strongly indicate that cokeable blends with acceptable ash contents may be produced from both.

The volatile matter of both Enugu and Bellview coals exceeds the limits of 30.3% for coals to be carbonized for cokemaking at Ajaokuta. However, the Bellview coal volatile matter is lower than 36-40% for Indian Jharia samples and 33-48% for coking coals indicated by Aderonpe (1996). The volatile content of Bellview is also lower than 39.4 and 41.8% for high volatile coals carbonized in Japan to produce coke that ensured the most efficient blast furnace operation (Katsuhiko *et al*., 1987). The successful carbonization of coals with specified volatiles exceeding the upper limit of 30.3% for Ajaokuta suggests that cokeable blends of Bellview and Enugu that satisfy international cokemaking practice may be produced despite their relatively high volatile contents.

The Gray-King coke type of G determined for Bellview coal is the same with Canadian Green Hill coal being carbonized in India. But the Indian Sudamih, Australian Utah and Polish Weglokoks coals with G1, G2 and G5 Gray-King Coke type numbers, respectively have better Gray-King coking power than Bellview coal (Parthasarathy, *et al*., 1987). The Gray-King coke type B determined for Enugu is lower than D for Indian Dugda II coal sample for cokemaking in India (Parthasarathy *et al*., 1987). Bellview coal has the same G value as the medium coking Kargali, Swang and prime coking Patherdith coals in use at Indian Sail plant for cokemaking (Parthasarathy *et al*., 1992). As expected, the coke yield for the medium coking Bellview exceeds that of non-coking Enugu, while the tar yield of the latter exceeds the former (Moitra *et al*., 1972). The high tar yield of Enugu coal may be an advantage in sourcing tar as a binder in the production of formed coke (Afonja, 1991). The Bellview coal with G as its Gray-King coke type may therefore be considered as cokeable while Enugu coal is obviously non-coking and may only blend with Bellview to an extent constrained by its poor plastic behaviour. The higher value of tar yield for Enugu coal in comparison with Bellview coal confirms it to be a lower rank coal with higher content of peripheral groups that produce tar (Moitra *et al*., 1972).

CONCLUSIONS

The proximate analysis, coke and tar yields obtained for Enugu and Bellview coals, showed that the latter is a medium coking bituminous coal suitable for cokemaking, while the former is a non-caking sub-bituminous coal with a higher tar content useable as a binder in formed coke production. The volatile content of Bellview coal can be reduced below the upper limit of 30.3% by blending with a low volatile prime coking bituminous coal. Bellview coal may also accommodate an amount of Enugu coal in blend to the extent constrained by the zero plastic property of the latter.

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REFERENCES

Aderonpe, W.I.A., 1996. Coal blending application of Nigerian coals for the iron and steel industries, in *Nigerian coal*. Raw Materials Research and Development Council, 132: 125 -126.

Afonja, A.A., 1991. New Techniques for low coking coal utilization in the blast furnace. Seminar on the potential of Nigerian Coals for Industries, Lagos.

Afonja, A.A., 1996. Production of metallurgical coke from non-coking coals, in *Nigerian coal*. Raw Material Research and Development Council, 132: 89-97.

Anonymous, 1987. On the maximum utilization of Nigerian coals at the Ajaokuta Steel Plant, Federal Ministry of Power and Steel, Abuja, Nigeria.

Federal Ministry of Mines, Power and Steel (FMPS) circular, 1992. On Coal Requirements for Ajaokuta steel Plant Operation.

Katsuhiko, O., A.K. Akira, H. Mitsumas, N. Seiji and A. Kan, 1987. Evaluation of coking coal. 1st International Cokemaking Congress, Preprints 1: Essen, Section E1.

Loison, R.,P. Foch and A. Boyer, 1989. Coke quality and production. 2nd Edn., London, Butterworths, pp: 37-38, 158, 190.

Moitra, A.K., N.G. Banerjee, K.Y. Shrinkhande, K. Sing, K. Raja and S. Banerjee, 1972. Studies on coal carbonization in India, Central Puel Research Institute Publicationm, pp: 17-23, 35-36.

National Metallurgical Development Centre (NMDC), 1994. On Pilot Scale Coal Carbonization Studies.

Parthasarathy, L., S.V.B. Subbarao, R.P. Sharma, C.R. Srinivason and R.K. Pathak, 1987. Efforts to improve the quality of coke from high ash, low fluidity Indian coals. 1st International Cokemaking Congress, Supplementary Volume, Section III 3.

Parthasarathy, L., R.P. Sharma, N.B. Gosh, V.U. Raju and K. Sharma, 1992. Coal selection and preparation steps towards improving coke quality in SAIL. 2nd International Cokemaking Congress, 2: 152-171.

Prasad, A.N., P.V.T. Rao, N.N. Poddar and A. charterjee, 1992. Selection of coals for cokemaking by classical top charging and stamp charging. 2nd International Cokemaking Congress, 2: 231-235.

Xiaofeng, X., O. Akira, N. Tsunenori and M. Shigeru, 1998. Properties and structures of brown coal treated by hydrothermal process, 8th Australian Coal Conference, pp: 145-146.