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DETERMINATION OF WORK INDEX OF GRAPHITE FROM SAMAN-BURKONO (NIGERIA) USING MODIFIED BOND'S METHOD

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ABSTRACT

This report covers the work index determination of Saman-Burkono graphite. The test sample was obtained from Saman-Burkono in Ningi Local Government Area of Bauchi state, while reference material (coal) was sourced from Okaba coal mine, Ankpa Local Government Area of Kogi State. A known weight of graphite sample and coal were crushed, pulverized and ground using the laboratory milling machine. The two samples were grinded with two cells of diameter 3.5cm and 222g weight. The analysis of the feed size fort the two samples was found graphically to be 180µm and 175µm, and ball mill discharge was 130µm and 140µm respectively. The work index of a coal as reference material was 7.65 kWh/ short ton, this was used to calculate the work index of the graphite which was found to be 11.047 kWh/short ton, being the required energy to comminute one ton of graphite.

Keywords: *Comminution, Graphite, Saman-Burkono, Nigeria, Modified Bonds method*

1. INTRODUCTION

The insufficiency of energy resources in this present decade has led to the proper analysis of the energy requirements for use in engineering processes. One important aspect of the mineral industry is the comminution which invariably becomes the highest consumer of energy. Napier-Munn [1] stated that 30 - 50 per cent of the total plant power consumption for mineral processing plants and up to 70 per cent for hard ores is attributed to comminution. Comminution in the mineral processing plant is the sequence of crushing and grinding process, it is a process in which solid material are reduced in size, Crushing is a process whereby the particle size of run-off-mine ore is reduced to such a level that grinding can be carried out until the mineral and gangues are substantially produced as separated particles [2, 3]. The grindability parameter which expresses the resistance of the material to crushing and grinding is known as Work index., numerically, it is the kilowatt hour per short ton required to reduce the material from theoretically infinite size to 80% passing 100 micron [3], work index determination using modified Bond's method can be compared to the method used by Berry and Bruce [4]. In this method, it requires the use of a reference ore of known grindability. Grindability can be defined as the ease with which materials can be broken into smaller particle sizes and the data obtained from these tests are used to calculate the required energy and grinding efficiency [5].

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Determination of the required energy to effect rock-breakage is of fundamental importance in process design and which is achieved through work index. It was observed by Whittles that about 1.5 per cent of the annual electrical energy production in the United States of America is used in comminuting processes in the minerals industry [6] . Graphite is a crystalline and an allotropes of carbon that occurs as mineral, they can be used in many ways because of its resistance to high temperature, corrosive chemicals and its non-wettedness.

Graphite materials are good conductivity of heat and electricity with good refractory properties. The usefulness of graphite is dependent largely upon its types, the flake type is found to possess extremely low resistivity decreasing with increase in flaky particles; it finds a large use in the manufacture of carbon electrodes, plates and brushes required in the electrical industry and dry cell batteries. In the manufacture of plates and brushes, however, flake graphite has been substituted to some extent by synthetic amorphous, crystalline graphite and acetylene black. Graphite electrodes serve to give conductivity to the mass of manganese dioxide used in dry batteries. The manufacture of crucibles is served best by flake graphite, although crystalline graphite is also used [7]. Graphite crucibles are manufactured by pressing a mixture of graphite, clay and sand, fixing the pressed articles at a high temperature. They are used for melting non- ferrous metals, especially brass and aluminum. Coarse-grained flake graphite from Malagasy is regarded as standard for crucible manufacture [8].

Therefore, energy required to grind one tonne of an ore from a given feed size to a specified product size is a material property that needs to be determined for different mineral deposits. This work aimed at the determination of work index of Saman-Burkono graphite ore. The study used Okaba coal as a reference material with a comparative method to determine the Bond's work index.

2. MATERIALS AND METHODS

2.1 Sample Collection

The graphite sample utilized in this research was obtained from the main bulk at Saman-Burkono graphite deposit in Ningi Local Government Area of Bauchi State, Nigeria, about 20 Kilometers away from Bauchi along Kano road with a coordinate of 11° 11′ 0″N, 9° 45′ 0″E, and has an area coverage of about10 hectares (100,000 square meters) of land, while the reference material was sourced from Okaba coal mine, Okaba town in Kogi State, using random sampling method. The samples were collected in lumps size at different lode (Bulk deposit) locations of 10meters apart and 30meters depth within the deposit

2.2 Sample Preparation

The graphite samples were crushed to size reduced from boulders to 10 mm size, this was further ground to pulverized size. Part of the pulverized sample was weighed for sieve analysis and part was weighed for ball mill operation for further size reduction (grinding).

2.3 Procedure for the Determination of Work Index Using Modified Bond's Method

The modified Bond's method for determining work index of an ore involves the use of reference ore of known grindability. Experimental procedures were as follows:

1. 100 g each of ore of graphite and coal samples were crushed and pulverized.
2. An identical weight of both samples were taken and sized by sieving into a number of size fractions using automatic sieve shaker for 10 minutes.
3. Each size fraction of the test and reference ores were weighed and the values noted as the "feed".
4. The "feed" test and reference ore were each gathered together and introduced into laboratory ball mill machine and ground for one hour.
5. The test and the reference ores from the laboratory ball mill machine were sized and each sieve fraction was weighed and the value noted as "product" or "discharge."
6. Sieve Size Analysis: The ground samples were sieved into the following sieve size fractions; 180 μm, 125 μm, 90 μm, 63 μm and 45 μm and these were arranged using root two (√2) method and were sieved for 10 minutes using automatic rotap sieve shaker.

2.4 Calculations of Result

From Table 1:

by proportion, if 125 μm = 67.54 %, then X = 80 %

Using Gaudin Schuman Expressions

$P(X) = 100(X/K)^x$

$X = \frac{\log P\ (X2 - P\ (X1)}{\log(X2) - \log(X1)}$

$Size_2 = \frac{(Percentage\ Passing\ size\ 2)2}{(percentage\ Passing\ Size\ 1)2}$ X $Size_1$

X µm = $(\frac{80/100}{67.54/100}) square$ X 125

= $\left(\frac{0.8}{0.68}\right) squre\ X\ 125$= 1.38 x 125 = 173.01 µm

From Table 2:

125 µm = 75.04 %, X µm = 80%

=$(\frac{80/100}{75.04/100})$ square X 125= 142.07 µm

From Table 3.

If 125 µm = 78.74, Then X = 80%

X µm = $(\frac{80/100}{78.74/100})^2$ x 125= $(\frac{0.8}{0.7874})^2$x 125 = 129.03 µm

From Table 4

If 180 = 80.2%, X µm = 80%

= $\left(\frac{\frac{80}{100}}{\frac{80.2}{100}}\right)^2$ X 180 = $(\frac{0.8}{0.82})$ x 180 = 171.33 µm

If r is the reference ore and t is the ore under test. From bond's equation: Then;

$$W = W_{it} = W_{ir} = \left[\frac{10}{\sqrt{P}} - \frac{10}{\sqrt{F}}\right] \quad (1)$$

$$W_{it} = W_{ir} = \frac{\frac{10}{\sqrt{P_r}} - \frac{10}{\sqrt{F_r}}}{\frac{10}{\sqrt{P_t}} - \frac{10}{\sqrt{F_t}}} \quad (2)$$

where: W_{ir} = work index of the reference ore

W_{it}= work index of the test ore

P_r= the diameter of the Okaba ore through which 80% of the product passes through 100µm

P_t= the diameter of the test ore through which 80% of the product passes through 100µm

F_r = the diameter of the reference ore through which 80% of the feed passes through 100µm

F_t =the diameter of the test ore through which 80% of the feed passes through 100µm

W_r = work input in kilowatt hour per short ton for the reference ore.

W_t = work input in kilowatt hour per short ton for the test ore.

F_t = 173.01 µm

P_t = 142.07 µm

F_r = 171.3 µm

P_r = 130µm

Substituting the values into equation 2.

$$W_{it} = W_{ir} = \frac{\frac{10}{\sqrt{129.8}} - \frac{10}{\sqrt{171.3}}}{\frac{10}{\sqrt{142.07}} - \frac{10}{\sqrt{173.01}}} = 7.65 \times 1.444 = 11.047$$ kWh/ton

3. RESULTS AND DISCUSSIONS

3.1 Results

Results of experiments carried out are presented in Tables 1 – 4.

Table 1: Result of sieve size analysis of the "feed" test material (Graphite).

Sieve size Range (µm)	Weight retained (g)	% weight retained	Nominal aperture	Cumulative % Weight retained	Cumulative % Weight passing
+180	18.37	18.37	180	18.37	81.63
-180+125	14.09	14.09	125	32.46	67.54
-125+90	15.31	15.31	90	47.77	52.23
-90+63	21.65	21.65	63	69.42	30.58
-63+45	18.62	18.62	45	88.04	11.96
-45	11.96	11.96	-	100	0.00

Table 2: Result of sieve size analysis of the "product" test material (Graphite).

Sieve size Range (µm)	Weight retained (g)	% weight retained	Nominal aperture	Cumulative %Weight Retained	Cumulative %Weight passing
+180	7.84	7.84	180	7.84	92.16
-180+125	17.12	17.12	125	24.96	75.04
-125+90	15.56	15.56	90	40.52	59.48
-90+63	25.15	25.15	63	65.67	34.33
-63+45	16.40	16.40	45	82.07	17.93
-45	17.93	17.93	-	100	0.00

Table 3: Result of sieve size analysis of the feed reference material (Okaba Coal)

Sieve size Range (μm)	Weight retained (g)	% weight retained	Nominal aperture	Cumulative % Weight retained	Cumulative % Weight passing
+180	19.80	19.80	180	19.80	80.20
-180+125	18.80	18.80	125	38.60	61.40
-125+90	11.50	11.50	90	50.10	49.90
-90+63	07.80	07.80	63	57.90	42.10
-63+45	01.60	01.60	45	59.50	40.50
-45	40.50	40.50	-	100	0.00

Table 4: Result of sieve size analysis of the "product" reference material (Okaba Coal)

Sieve size Range (μm)	Weight retained (g)	% weight retained	Nominal aperture	Cumulative % Weight retained	Cumulative % Weight passing
+180	06.00	06.00	180	06.00	94.00
-180+125	15.26	15.26	125	21.26	78.74
-125+90	20.03	20.03	90	41.29	58.71
-90+63	23.40	23.40	63	64.69	35.31
-63+45	11.77	11.77	45	76.46	23.54
-45	23.54	23.54	-	100	0.00

4. DISCUSSIONS OF RESULTS

Tables 1– 4 shows the results in tabular form, the results shows the particle size fractions of the graphite material and the coal as reference ore, show a normal distribution pattern, indicating that the particle size fractions responded to the theories of comminution. That is, the energy consumed in size reduction is proportional to the area of new surface produced [9]. The 80% passing is obtained to be 171.3 μm and 129.8 μm for the reference material (Feed & Product) and 173.01μm, 142.07 μm for the test ore respectively. This gave an average work index of the as-received Saman-Burkono graphite to be 11.047 kWh/ton. The computed work index is within work indices of other graphite mineral used as standard that fall between 1.75-45.03 kWh/ton sighted in the literatures [1, 10, 11]. The value obtained proved that 11.047 kWh/hr. of energy is required to reduce one tonne of the as – received graphite ore sample from 80% passing sieve size 173.01 μm to 80% passing sieve size of 142.07 μm. This ore is therefore by this result termed as ore "type B" of Denver grindability curves [9, 10, 13].

5. CONCLUSION

In conclusion, the determination of work index of Saman-Burkono graphite, Bauchi State, Nigeria was investigated using modified Bond's Energy method. From the results of the experiments the work index was found to be 11.047 kWh/ton; considering the economic implication it indicates that the cost of energy used to comminute one ton of the study ore to 80 % passing 100 microns will cost ₦303.79k at a unit cost of ₦27.5k per energy- being a unit cost of power consumption by industries in Nigeria [12].This parameter is significant for use in the design of a process route for the beneficiation of the Saman–Burkono graphite.

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