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Determination of Work Index of Arufu Lead Ore, Nasarawa State, North-Central Nigeria

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----------ABSTRACT----------
In this research, work index of the Run off Mine Arufu lead ore was determined. The test sample was obtained from Arufu village in Nasarawa State . A reference material granite was sourced from Anguwan-Boro Sabon, Kaduna metropolis. *A known weight of reference and test material were crushed, pulverized and ground using the laboratory ball mill machine. The cell used in grinding the two samples has twelve steel balls of diameter 3.5cm and 222g weight. The size analysis of the feed for both reference and test material was found to be 218.2 and 198.4µm, and ball mill discharge was 189.9 and 170.1µm respectively. The granite as a reference material with work index of 15.13kwh/ short ton was used to calculate the work index of the test material which was found to be 12.73kwh/short ton, being the energy required to comminute one tone of the ore.*

KEYWORDS*: Bond's index, Arufu Lead Ore, modified, reference mineral, mineral processing*

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I. INTRODUCTION

Comminution is a process in which solid material are reduced in size, this take place in mineral processing plant as a sequence of crushing and grinding process. Crushing reduces the particle size of run-off-mine ore to such a level that grinding can be carried out until the mineral and gangues are substantially produced as separated particles (Wills, 2006). Work index is the comminuting parameter which expresses the resistance of the material to crushing and grinding, numerically; it is the kilowatt hour per short ton required to reduce the material from theoretically infinite size to 80% passing 100 micron, (Magdalimovic,1989). In another development, Determination of work index using modified Bond's method can be compared to the method used by Berry and Bruce (1966). This method requires the use of a reference ore of known grindability. Determination of the required amount of energy to effect rock-breakage is of fundamental important in process design and which is achieved through work index . Therefore, the need to determine the work index of Arufu lead ore necessitated this research work in order to serve as invaluable repository to all stakeholders.

II. MATERIALS AND METHODS

Sample Collection

The sample used in this research work was obtained from the main bulk at Arufu Lead Ore deposit while a reference material (granite) was sourced from Anguwan-Boro Sabon, Kaduna metropolis, using random sampling method. The samples were collected in lumps size at different locations by 30m apart within the deposit.

Sample Preparation

The samples collected in lumps size were broken manually with sledge hammer to provide a required size acceptable to laboratory jaw crusher. The samples were crushed and pulverized, part of the pulverized samples were weighed for sieve analysis and part were weighed for ball mill for further size reduction (grinding).

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

The modified Bond's method of determine work index of an ore involves the use of reference ore of known grindability.

The procedures were as follow;

1. 200g each of ore samples under test and the reference ores were each crushed and pulverized.
2. An identical weight of test and reference ores 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 was weighed and the value 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 fractions 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; 250 µm, 180 µm, 125 µm, 90 µm and 63 µm, these were arranged using root two (√2) method and were sieved for 10 minutes by automatic rotap sieve shaker.

III. RESULTS AND DISCUSSIONS

Table 1: Result of sieve size analysis of the "feed" reference material (Granite)

If 180µm ⟶ 66.00%
X µm ⟶ 80%

Sieve size Range (µm)	Weight retained (g)	% weight retained	Nominal aperture	Cumulative % Weight retained	Cumulative % Weight passing
+250	31.48	15.74	250	15.74	84.26
-250+180	36.52	18.26	180	34.00	66.00
-180+125	44.06	22.03	125	56.03	43.97
-125+90	36.80	18.40	90	74.43	25.57
-90+63	23.54	11.77	63	86.20	13.80
-63	27.60	13.80	-	100	0.00

$$X\ \mu m = \frac{180 \times 80}{66.00} = 218.2\mu m \text{ at } 80\%$$

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Table 2: Result of sieve size analysis of the product reference material (Granite)

Sieve size Range (µm)	Weight retained (g)	% weight retained	Nominal aperture	Cumulative % Weight retained	Cumulative % Weight passing
+250	16.66	8.33	250	8.33	91.67
-250+180	31.72	15.86	180	24.19	75.81
-180+125	40.82	20.41	125	44.60	55.40
-125+90	21.42	10.71	90	55.31	44.69
-90+63	47.60	23.80	63	79.11	20.89
-63	41.78	20.89	-	100	0.00

If 180µm ⟶ 75.81%

X µm ⟶ 80%

$$X = \frac{180 \times 80}{75.81} = 189.9\mu m \text{ at } 80\%$$

Table 3: Result of sieve size analysis of the feed test material (Lead)

Sieve size Range (µm)	Weight retained (g)	% weight retained	Nominal aperture	Cumulative % Weight retained	Cumulative % Weight passing
+250	26.48	13.24	250	13.24	86.76
-250+180	28.32	14.16	180	27.40	72.60
-180+125	30.02	15.01	125	42.41	57.59
-125+90	24.86	12.43	90	54.84	45.16
-90+63	35.60	17.80	63	72.64	27.36
-63	54.72	27.36	-	100	0.00

If 180µm ⟶ 72.60

X µm ⟶ 80%

$$X = \frac{180 \times 80}{72.60} = 198.4\ \mu m \text{ at } 80\%$$

Table 4: Result of sieve size analysis of the "product" test material (Lead).

Sieve size Range (µm)	Weight retained (g)	% weight retained	Nominal aperture	Cumulative % Weight retained	Cumulative % Weight passing
+250	13.56	6.78	250	6.78	93.22
-250+180	17.14	8.57	180	15.35	84.65
-180+125	26.40	13.20	125	28.55	71.45
-125+90	22.06	11.03	90	39.58	60.42
-90+63	32.70	16.35	63	55.93	44.07
-63	88.14	44.07	-	100	0.00

If 180 µm ⟶ 84.65

X µm ⟶ 80%

$$X = \frac{180 \times 80}{84.65} = 170.1\mu m \text{ at } 80\%$$

Calculations of Result

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

Then;

$$W = W_t = W_{ir}\left(\frac{10}{\sqrt{P_r}} - \frac{10}{\sqrt{F_r}}\right) = W_{it}\left(\frac{10}{\sqrt{P_t}} - \frac{10}{\sqrt{F_t}}\right)$$

Therefore

$$W_{it} = W_{ir}\left(\frac{10}{\sqrt{P_r}} - \frac{10}{\sqrt{F_r}}\right) \Big/ W_{it}\left(\frac{10}{\sqrt{P_t}} - \frac{10}{\sqrt{F_t}}\right)$$

Where;

W_{ir} = work index of the reference ore

W_{it} = work index of the test ore

P_r = the diameter of the reference ore through which 80% of the product passing 100µm

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

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

F_t = the diameter of the test ore through which 80% of the feed passing 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 = 198.4
P_t = 170.1
F_r = 218.2
P_r = 189.9

$$W_{it} = W_{ir}\left(\frac{10}{\sqrt{P_r}} - \frac{10}{\sqrt{Fr}}\right) \Big/ W_{it}\left(\frac{10}{\sqrt{P_t}} - \frac{10}{\sqrt{F_t}}\right)$$

Therefore;

$$W_{it} = 15.13 \left(\frac{10}{} - \frac{10}{} \right) \Big/ \left(\frac{10}{} - \frac{10}{} \right)$$

$$W_{it} = 15.13 \left(\frac{10}{13.78} - \frac{10}{14.77} \right) \Big/ \left(\frac{10}{13.04} - \frac{10}{14.08} \right)$$

$W_{it} = 15.13 \times 0.0488 / 0.058$

$W_{it} = 12.73$Kwh/tone.

IV. DISCUSSIONS OF RESULTS

From the result of the experiment performed on Arufu Lead Ore, Nasarawa State using modified Bond's Energy method, the 80% passing was obtained to be 218.2µm and 189.9µm for the reference material (Feed & Product) as shown in table 1 and 2 and 198.4µm, 170.1µm for the test ore (Feed & Product) as shown in table 3 and 4 respectively. The work index of Arufu Lead Ore, Nasarawa State was calculated to be 12.73kwh/ short ton, it is within the limit of the previous research on lead work index. (Weiss,1965).

V. CONCLUSIONS AND RECOMMENDATONS

Conclusion

The determination of work index of Arufu Lead Ore was investigated using modified Bond's Energy method. From the results of the experiments the work index was found to be 12.73kwh/ton, this means that, it will cost #350.08 (when taking #27.50 being a unit cost of power consumption in Nigeria), to comminute one tone of Arufu Lead Ore to 80% passing 100 microns.

Recommendation

It is therefore recommended that further work should be done especially to determine the reserve estimates of the deposit as well as beneficiation routes for optimal recovery.

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