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A Study on work Index Evaluation of Ishiagu Galena ore Ebonyi State, Nigeria

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ABSTRACT: *The study on work index evaluation of Ishiagu galena ore has been carried out. Quartz and Granite obtained from the same location at a distance of 40m apart from lead ore deposit were used to determine the Bond's work index of the lead ore. The samples were crushed, ground and pulverized using a ball mill. The sieve analysis for both the feed (test) and the reference material was carried using an automatic sieve shaker. The size fractions of feed for the both test and reference materials was found to be 1593.88µm for lead ore, 1426.99µm for quartz and 1121.97µm for granite respectively. The ball mill discharge (product) was 335.85µm for lead ore, 740.37µm for quartz and 782.78µm for granite. Using Bond energy method, 5.14Kwh/t was required to grind 1000kg of test ore to 80% passing sieve size of 100µm.*

Keywords: *Discharge, Feed, Particle size, Work index, Samples.*

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I. INTRODUCTION

It has been proven that Nigeria is endowed with lots of solid minerals including but not limited to precious metals, stones and industrial minerals. However not all minerals are available in commercial quantities. The Federal Ministry of Mines have found over five hundred (500) locations of mineral deposits in the country and identified nine (9) that they would want to concentrate and promote, these include Coal , Tin ore, Gold, Bitumen, Iron ore, Columbite –Tantalite, Lead-Zinc, Wolframite and Industrrial minerals, [1]. Lead ore (PbS – ZnS) are usually found together. It is generally associated with other sulphide minerals such as copper, silver, gold etc. In Nigeria, it is found naturally in commercial quantities, it's mineralization was observed along a belt some of 30-50 kilometers wide and extending from Ishiagu in Ebonyi state through Benue, Adamawa, Taraba, Nasarawa and Plateau states to Bauchi state. In Ebonyi state South East of Nigeria, its occurrence are known at Ameka, Ameri, Enyigba and Ishiagu district which banded by longitudes 7^0 $29^{'}$ -7^0-35E and latitude 5^0 $43^{'}$ -5^0 $51^{'}$ N, [2]. In 2002, [3]the estimated reserve is well over 2 - 2.5 million tonnes of combined lead, whose commercial deposits ceased during the civil war. The determination of accurateestimate of mineral deposits is a complex exercise as new discoveries are made,[4]. Further, records showed that Ishiagu ore has an estimated reserve of 15million tonnes,[5][6].

In the mineral industry, mineral processing is a critical stage in the primary production of high quality mineralogical concentrates from ores. This is accomplished via communition which as a sequence of crushing and grinding processes. Communition is the highest consumer of energy, in 1996, records showed that 30-50 % of the total plant power consumption for mineral processing plants and up to 70 % for hard ore is attributed to communition[7][8]. It was observed that about 1.5% of annual electric energy production in United states of America is used in communition processes[9]. Crushing reduces the particle size of run off mine ore to significant level that grinding can be carried out until the mineral and gangue are substantially produced as separate articles, [10]. Grindability is the ease with which the mineral can be communted and the data obtained from the grindability tests are used to evaluate the energy requirement and grinding efficiency. The most commonly used parameter to measure ore grindability is the bond work index, [11]. The bond ball mill index test is a standard test for determining the ball mill work index of a sample ore, [8] [10]. The work index expresses the resistance of the material to crushing and grinding. Numerically, work index is the energy required in kilowatt hour per short ton (KWHT) to reduce a given material from theoretical infinite size to 80% passing size of 100µm [11] [12].The determination of work index using Bond's modified method can be compared to the method used by,[13]. The method requires the use of reference ore of known grind ability. The objective of this study is to determine the work index of Ishiagu lead ore.

II. MATERIALS AND METHODS

Ishiagu galena ore was obtained from seven different points of different depth ranges using within the sampling techniques within the study area, in order to have a true fraction representation of galena from the bulk. Reference samples collected include granite and quartz from the same location by 40m apart. The samples collected in lump sizes were broken manually with sledge hammer to provide a required size acceptable to laboratory cone crusher. 20kg of each sample was crushed, pulverized, and analyzed with sieve.

The Modified Method Of Determining The Work Index Of Ore Involved The Use Of Reference Ore Of Which Grindability Is Known. The Procedure Was As Follows:

1. 100g each of ore samples under test and the reference ores were crushed and pulverized.
2. The samples of test and reference one were sized into a number of size fractions using the automatic sieve shaker for 15minutes.
3. Each size fraction of the test and reference ore were weighed and the values noted as "feed"
4. The "feed" test and references ores were each gathered together and introduced into the laboratory mill machine and ground for 15minutes.
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. Sieze size analysis:

The ground samples were sieved into the following sieve size fractions; +1400µm, -1400 +1000µm, 1000 +710µm, -710 +500µm, -500 +355µm, -355 +250µm, -250 +180µm, -180 +125µm, -125 +90µm, -90 +63µm, -63µm using automatic sieve sharker for 15minutes

III. DISCUSSION OF RESULTS

Table 1 – 6: showing particle size distribution for feed (ore) and product from ball bill.

Table 1: Result of sieve analysis of the feed sample (lead ore) to ball mill

Sieve Size	Weight	Weight Retained	Cummulative Weight (%)	
(Mm)	(G)	(%)	Retained	Passing
+ 1.4	**24.7**	**25.00**	**25.00**	**75.00**
-1.4 + 1.0	**8.3**	**8.40**	**23.40**	**66.60**
-1.0 + 0.71	**9.3**	**9.41**	**42.81**	**57.19**
-0.71 + 0.500	**11.1**	**11.23**	**54.04**	**45.96**
-0.500 + 0.355	**7.3**	**7.39**	**61.62**	**38.57**
-0.355 + 0.250	**7.1**	**7.19**	**68.62**	**31.38**
-0.250 + 0.180	**6.0**	**6.07**	**74.69**	**25.31**
-0.180 + 0.125	**7.6**	**7.69**	**82.38**	**17.62**
-0.125 + 0.090	**8.6**	**8.70**	**91.06**	**8.94**
-0.090 + 0.063	**3.6**	**3.64**	**94.72**	**5.28**
-0.063	**5.2**	**5.26**	**100**	
	98.8			

If 1400 = 75.0%

x = 80%

Gaudin Schumann expression

$$\text{Size}_2 = \frac{(percentage \quad passing \ size_2)^2}{(percentage \quad passing \ size_1)^2} \times size_1$$

$$Xum = \left(\frac{\frac{80}{100}}{\frac{75}{100}}\right)^2 \times 1400$$

$$= \left(\frac{0.8}{0.75}\right)^2 \times 1400$$

$$= (1.067)^2 \text{ X } 1400$$

$$= 1593.88 \ @ \ 80\%$$

Table 2: Result of sieve analysis of product (lead ore) to ball mill

SIEVE SIZE (mm)	WEIGHT (g)	WEIGHT RETAINED	CUMMULATIVE WEIGHT (%)	
		(%)	RETAINED	PASSING
+ 1.4	-	-	-	-
-1.4 + 1.0	**0.08**	**0.08**	**0.08**	**99.92**
-1.0 + 0.71	**0.52**	**0.52**	**0.60**	**99.40**
-0.71 + 0.500	**0.42**	**0.42**	**1.02**	**98.98**
-0.500 + 0.355	**0.26**	**0.26**	**1.28**	**98.72**
-0.355 + 0.250	**0.58**	**0.58**	**1.86**	**98.14**
-0.250 + 0.180	**39.89**	**40.00**	**41.86**	**58.14**
-0.180 + 0.125	**31.41**	**31.49**	**73.35**	**26.65**
-0.125 + 0.090	**16.40**	**16.44**	**89.79**	**10.21**
-0.090 + 0.063	**6.31**	**6.32**	**96.11**	**3.90**
-0.063	**3.88**	**3.89**	**100.00**	**0**
	99.75			

180 µm = 58.14

X = 80%

$$= \frac{(80/100)^2}{(58.14/100)^2} \times 180$$

$$= \left(\frac{0.8}{0.5814}\right)^2 \times 180$$

$= (1.356)^2$ X 180

= 335.85µm@80%

Table 3: Result of sieve analysis of the "feed" (reference ore) to ball mill (Quartz)

Sieve Size (Mm)	Weight (G)	Weight Retained	Cummulative Weight (%)	
		(%)	Retained	Passing
+ 1.4	**22.10**	**21.72**	**21.72**	**78.28**
-1.4 + 1.0	**13.61**	**13.99**	**35.71**	**64.29**
-1.0 + 0.71	**13.72**	**14.10**	**49.81**	**50.19**
-0.71 + 0.500	**10.89**	**11.20**	**61.01**	**38.99**
-0.500 + 0.355	**9.81**	**10.08**	**71.09**	**28.91**
-0.355 + 0.250	**10.08**	**10.36**	**81.45**	**18.55**
-0.250 + 0.180	**7.81**	**8.03**	**89.48**	**10.52**
-0.180 + 0.125	**4.99**	**5.13**	**94.61**	**5.39**
-0.125 + 0.090	**2.12**	**2.18**	**96.79**	**3.21**
-0.090 + 0.063	**1.57**	**1.61**	**98.40**	**1.60**
-0.063	**0.59**	**1.60**	**100.00**	**-**
	97.29			

1400 = 78.24

80% = X

$$X\mu m = \left(\frac{\frac{80}{100}}{\frac{78.24}{100}}\right)^2 \; X\ 1400$$

$= (1.022)^2$ X 1400

= 1426.99 µm @ 80%

Table 4: Result of sieve analysis of product (reference ore) to ball mill (Quartz)

Sieve Size (Mm)	Weight (G)	Weight Retained	Cummulative Weight (%)	
		(%)	Retained	Passing
+ 1.4	-	-	-	-
-1.4 + 1.0	**4.60**	**4.61**	**4.61**	**95.39**
-1.0 + 0.71	**19.01**	**19.06**	**21.67**	**78.33**
-0.71 + 0.500	**12.87**	**12.90**	**36.57**	**63.43**
-0.500 + 0.355	**18.32**	**18.36**	**54.93**	**45.07**
-0.355 + 0.250	**25.99**	**26.05**	**80.98**	**19.02**
-0.250 + 0.180	**9.32**	**9.34**	**90.32**	**9.68**
-0.180 + 0.125	**5.88**	**5.89**	**96.21**	**3.79**
-0.125 + 0.090	**2.38**	**2.39**	**98.61**	**1.39**
-0.090 + 0.063	**0.80**	**0.80**	**99.41**	**0.59**
-0.063	**0.59**	**0.59**	**100**	**0**

	99.76			

710 = 78.83

Xµm = 80%

$$X\mu m = \left(\frac{\frac{80}{100}}{\frac{78.33}{100}}\right)^2 X\ 710$$

= (1.021)^2 X 710

= 740.37µm@80%

Table 5: Result of sieve analysis of (reference ore) "feed" to ball mill Granite

Sieve Size (Mm)	Weight (G)	Weight Retained (%)	Cummulative Weight (%) Retained	Passing
+ 1.4	0.42	10.42	10.42	89.58
-1.4 + 1.0	14.06	14.07	24.49	75.51
-1.0 + 0.71	13.34	13.35	37.84	62.16
-0.71 + 0.500	13.99	14.00	51.84	48.16
-0.500 + 0.355	12.26	12.26	64.10	35.9
-0.355 + 0.250	9.90	9.90	74.0	26.0
-0.250 + 0.180	9.31	9.31	83.31	16.69
-0.180 + 0.125	6.10	6.10	89.41	10.59
-0.125 + 0.090	4.66	4.66	94.07	5.93
-0.090 + 0.063	3.53	3.53	97.61	2.39
-0.063	2.39	2.39	100	-
	99.96			

1000µm = 75.51

Xµm = 80%

$$X\mu m = \left(\frac{\frac{80}{100}}{\frac{75.51}{100}}\right)^2 X\ 100$$

= (1.059)^2 X 1000

= 1121.97µm @ 80%

Table 6: Result of sieve analysis of product (reference ore) to ball mill (granite)

Sieve Size (Mm)	Weight (G)	Weight Retained (%)	Cummulative Weight (%) Retained	Passing
+ 1.4	-	-	-	-
-1.4 + 1.0	14.22	14.28	14.28	85.72
-1.0 + 0.71	9.48	9.52	23.80	76.20
-0.71 + 0.500	11.97	12.02	35.82	64.18
-0.500 + 0.355	2.34	2.35	38.17	61.83
-0.355 + 0.250	22.82	22.92	61.09	38.9
-0.250 + 0.180	27.30	27.42	88.52	11.49
-0.180 + 0.125	2.78	2.78	91.30	8.70
-0.125 + 0.090	2.76	2.76	94.07	5.93
-0.090 + 0.063	4.09	4.09	98.18	1.82
-0.063	1.03	1.03	99.21	0.79
Total	0.79	0.79	100	0
	99.58			

710µm = 76.2

Xµm = 80%

$$X\mu m = \left(\frac{\frac{80}{100}}{\frac{76.2}{100}}\right)^2 X\ 710$$

= (1.050)^2 X 710

= 782.78µm @ 80%

IV. WORK INDEX CALCULATION

	Bond Ball's Work Index, $W_{it} = w_{ir} \frac{\left(\frac{10}{\sqrt{P_{r1}}} - \frac{10}{\sqrt{F_{r1}}}\right)}{\left(\frac{10}{\sqrt{P_t}} - \frac{10}{\sqrt{Ft}}\right)}$	
	Where $P = T \times W$ W = work input (Khw/t) W_i = work index (Khw/t) P = power draw (KW) T = throughput of new feed (t/h) F_{80} = 80% passing size of feed (μm) P_{80} = 80% passing size of product (μm)	

Work index calculations:

When Quartz was used as reference ore

W_{it} = Quartz (13.57)

	$= \frac{\frac{10}{\sqrt{740.37}} - \frac{10}{\sqrt{1593.88}}}{\frac{10}{\sqrt{33.85}} - \frac{10}{\sqrt{1593.88}}}$	
	$= \frac{\frac{10}{27.2} - \frac{10}{38.25}}{\frac{10}{18.23} - \frac{10}{39.92}} \times 13.57$	
	$= \frac{0.3675 - 0.2614}{0.5456 - 0.2505}$ X 13.57	
	$= \frac{0.1061}{0.2951} \times 13.57$	
	$= 4.879 kw/ton$ (work index of test ore (lead) using quartz reference ore)	

When Granite (Ore) was used as Reference Sample

Work index of test ore when granite was used.

Granite (15.13)

	$W_{it} = \frac{\frac{10}{\sqrt{782.78}} - \frac{10}{\sqrt{1121.97}}}{\frac{10}{\sqrt{33.85}} - \frac{10}{1593.88}} \times 15.13 = \frac{\frac{10}{27.98} - \frac{10}{33.50}}{\frac{10}{18.33} - \frac{10}{39.92}} \times 15.13$	
	$= \frac{0.3574 - 0.2985}{0.5456 - 0.2505} \times 15.13 = \frac{0.0589}{0.2951} \times 15.13$	
	$= 0.1996 \times 15.13 = 3.02$ KWh/ton	

Therefore, work index $= \frac{4.879+3.02}{2} = \frac{3.949 kwh}{ton}$

Using dry grinding multiplication factor = 1.3

Therefore, Work index = (3.949 X 1.3) kwh/ton = 5.134kwh/ton.Means 5.134 kwh energy will be used to grind 1000g of test ore to 80%. Passing sieve size of 100μm.

The results obtained from the experiment performed on Ishiagu lead ore, Ebonyi state using modified Bond's energy method, Table 1 and 2 showed that 80% passing was obtained to be 1593.88μm and 335.85μm for test material for feed and product, 1426.99μm and 740.37μm for reference ore (quartz) Table 3 and 4 (feed and product). 1121.97μm and 78278μm were obtained for reference ore (granite) as shown in Table 5 and 6 respectively. The work index of Ishiagu lead ore, Ebonyi state was found to be 4.879 Kwh/ton and 3.02 Kwh/ton using Quartz and granite as reference ore respectively.The work index of Ishiagu Lead Ore, Ebony State was calculated to be 5.134kwh/ short ton.

V. CONCLUSION

The Bond's work index of IshiaguEbonyi state Nigeria was determined in this study. The result obtained from the study was found to be 5.134Kwh/t.

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