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Assessing the Grindability Behaviour of Anka (Zamfara State, Nigeria) Manganese Ore towards Effective Manganese Mineral Liberation

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Short Research Article

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ABSTRACT

The Bond standard grindability test provides a Work Index that is widely used to estimate the energy required for ore grinding. The research investigates the work index of Anka Manganese ore at Anka deposit in Zamfara state, Nigeria. The reference ore (Quartz) was sourced from the studied ore overburden in the mine. The test ore and the reference ore were characterized using Energy Dispersive X-ray fluorescence spectrometer, X - ray Diffractometer and the Scanning Electron Microscope equipped with Energy Dispersive Spectrum. 500 g each of the manganese ore and quartz were sampled and prepared by crushing and grinding to 100% passing 1200 μm sieve. 100 g of prepared ores were charged into array of sieve arranged in √2 series from 1000 μm to 63 μm. Set of sieves were mounted on the Automated Pascal Denver sieve shaker (16153) and was in operation for 20 minutes. The work index of reference ore was used to calculate the work index of the test ore using Gaudin Schuman expression to obtain a work index of 14.16 Kwh/ton for test ore and it lies within the work index of 10-15.14 Kwh/ton for manganese ore stated in the literature and the energy expended to achieve communition at mineral liberation size was calculated to be 3.3984 Kw/ton.

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1. INTRODUCTION

Manganese ore is an important and indispensable input raw material for steel making and steel production and its consumption is among the key indicators of industrial development in any country [1-3]. Ore is an aggregate of economically important minerals from which a valuable metallic constituent can be profitably extracted within an ore body; the valuable minerals are surrounded by gangue minerals. It is due to this primary reason; there's need for mineral processing. It is necessary to liberate and concentrate those valuable minerals from the bulk mass through suitable concentration techniques [4]. Mineral processing involves the enrichment of concentrate by separating the grains of valuable mineral from the gauge and since most ore minerals are usually finely intimately associated with gangue minerals, the various minerals must be liberated before they can be collected as separate products. Therefore, the first part in mineral processing involves the crushing and grinding which is also known comminution of the ore which is the gradual reduction in size of the particles [5,6]. Therefore, the objective of this study is to determine the grindability behaviour of Anka Manganese ore.

1.1 Work Index Determination

The work index is the energy required to reduce a given material from theoretical infinite size to 80% passing size of 100 µm and the Bond index method is useful in designing of grinding system as its parameters are used to measure ore grindability which involve the use of a test ore and reference ore [7-9]. The method requires the use of a reference ore with a known energy requirement value. The determination of work index of an ore will help in calculating the energy requirement for communition of the ore and selection of appropriate communition equipment. Using the modified bond's equation the work Index of an ore is determined by;

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

$$W_{it} = W_{ir} \times \left(\frac{\frac{10}{\sqrt{Pr}} - \frac{10}{\sqrt{Fr}}}{\frac{10}{\sqrt{Pt}} - \frac{10}{\sqrt{Ft}}}\right) \quad (2)$$

Where;

W_{it} is the work index of test ore
W_{ir} is the work index of reference ore
P_r is the diameter of the reference ore through which 80% of the product passes through 100µm
P_t is the diameter of the test ore through which 80% of the product passes through 100 µm F_r is the diameter of the reference ore through which 80% of the feed passes through 100µm F_t is thediameter of the test ore through which 80% of the feed passes through 100µm W_r is the work input for the reference ore. W_t is the work input for the test ore [7-9].

2. MATERIALS AND METHODS

2.1 Materials

5kg sample of Anka Manganese ore of which 2 kg of the sample used in this research work was obtained from the Anka deposit located in the northern axis of Zamfara state bounded by the geological coordinates, latitude 12°06'30"N and longitude 5°56'00"E which is a reserve that is still under investigation by the Nigerian Geological Survey (NGS). The quartz sample used as reference ore was sourced from Anka deposit overburden, in Zamfara state.

2.2 Method

The modified Bond's method was used to determine the work index of ore which involves the use of a reference with a known grindability value. The sample of the reference ore (Quartz) was broken with a sledge hammer to provide required size acceptable as feed to the Fritsch Pulveristte Laboratory Jaw Crusher (Model LF6797AC). 100 g each of the test (Anka Manganese) and the reference ore (Quartz) were crushed. 100 g each of the test and reference samples were then charged into the set of sieves which was placed on the Automated Pascal Denver sieve shaker (16153) which vibrates the sieve in a vertical plane for 20 minutes and each sieve fraction retained of the test and reference ore were weighed and the value noted as the feed product. 100 g each from crushed samples was pulverized in the Denver Laboratory Milling Machine (Size: D-12) and was also charged into the set of sieves which was placed on the Automated Pascal Denver sieve shaker (16153) which vibrates the sieve in a vertical plane for 15 minutes and each sieve fraction retained of the test and reference ore were weighed and the value noted as the milled product.

Plate 1. Sequential order of Manganese ore sample collection and preparation

3. RESULTS AND DISCUSSION

3.1 Results

Table 1. Sieve Analysis of Anka Manganese Ore (Test Ore) Feed to Ball Mill

Sieve size range (μm)	Weight retained (g)	% Weight Retained	% Cumulative weight retained	%Cumulative weight passing
+1000	2.50	2.51	2.51	97.49
-1000+710	1.50	1.50	4.01	95.99
-710+500	22.30	22.35	26.36	73.64
-500+355	16.40	16.43	42.79	57.21
-355+250	12.30	12.32	55.11	44.89
-250+180	9.70	9.72	64.83	35.17
-180+125	9.30	9.32	74.15	25.85
-125+90	7.60	7.61	81.76	18.24
-90+63	10.10	10.12	91.88	8.12
-63	8.10	8.12	100	0

Table 2. Sieve analysis of quartz (Reference Ore) feed to ball mill

Sieve size range (μm)	Weight retained (g)	% Weight Retained	%Cumulative weight retained	%Cumulative weight passing
+1000	0.70	0.71	0.71	99.29
-1000+710	1.60	1.62	2.33	97.67
-710+500	28.20	28.51	30.84	69.16
-500+355	18.70	18.91	49.75	50.25
-355+250	13.30	13.45	63.20	36.80
-250+180	10.20	10.31	73.51	26.49
-180+125	13.50	13.65	87.16	12.84
-125+90	5.20	5.26	92.42	7.52
-90+63	5.0	5.06	97.48	2.52
-63	2.5	2.52	100	0

Table 3. Sieve analysis of Anka manganese Ore (Test Ore) milled product from ball mill

Sieve size range (μm)	Weight retained (g)	%Weight retained	%Cumulative weight retained	% Cumulative weight passing
+1000	-	-	-	-
-1000+710	-	-	-	-
-710+500	0.60	0.60	0.60	99.4
-500+355	1.20	1.21	1.81	98.19
-355+250	18.60	18.71	20.52	79.48
-250+180	12.40	12.47	32.99	67.01
-180+125	16.20	16.30	49.29	50.71
-125+90	15.30	15.40	64.69	35.31
-90+63	16.50	16.60	81.29	18.71
-63	18.60	18.71	100	0

Table 4. Sieve analysis of quartz (Reference Ore) milled product from ball mill

Sieve size range (μm)	Weight retained (g)	% Weight Retained	%Cumulative weight retained	%Cumulative weight passing
+1000	-	-	-	-
-1000+710	-	-	-	-
-710+500	0.70	0.70	0.70	99.30
-500+355	1.60	1.61	2.31	97.69
-355+250	15.40	15.48	17.79	82.21
-250+180	12.40	12.46	30.25	69.75
-180+125	16.80	16.88	47.13	52.87
-125+90	16.30	16.38	63.51	36.49
-90+63	15.30	15.38	78.89	21.11
-63	21.00	21.11	100	0

3.1.1 Evaluation of grindability

Evaluation of grindability was carried out using equation 3;

Thus; $R = \frac{F}{P}$ (3)

Where

R = Reduction Ratio
F = Diameter of feed particles
P = Diameter of product particles

Using Gaudin Schumann Expression

$P(X) = 100\,(X \div K)^{\alpha}$

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

$\text{Sieve 1} = \frac{\%\,passingsieve\ 1}{\%\,passingseive\ 2} \times \text{Sieve 2}$ (4)

X = Sieve mesh size with 80% of particle size passing

Table 5. Sieve mesh size (500 μm and 250 μm) with 80% of particle size passing

Sample	80% Passing of Feed Product (μm) (F)	80% Passing Milled Product (μm) (P)
Test Ore	591	236.75
Reference Ore	663.5	253.75

3.1.2 Work index determination

Work index of test ore (W_{it}) was calculated using values in Table 5 substituted in Equations 1 and 2 respectively, with known work index of reference ore (Quartz) of 14.1 Kwh/ton. Therefore, W_{ir} = 14.1, substituting this in equation 2.

$$W_{it} = 14.1 \times \left(\frac{\frac{10}{\sqrt{253.75}} - \frac{10}{\sqrt{663.5}}}{\frac{10}{\sqrt{236.75}} - \frac{10}{\sqrt{591}}}\right) = 14.16 \text{ Kwh/ton}$$

3.1.3 Energy expended in grinding determination

Energy expended in achieving liberation size during communition was achieved by substituting test work index into Equation 1.

$$W_t = 10W_{it} \times \left(\frac{1}{\sqrt{236.75}} - \frac{1}{\sqrt{591}}\right) = 10 \times 14.16 \times \left(\frac{1}{\sqrt{236.75}} - \frac{1}{\sqrt{591}}\right) = 3.3984 \text{ Kwh}$$

3.2 Discussion

Table 1 – 5 present the result of the grindabilty of Anka Manganese ore as Test ore using Quartz as Reference ore (Overburden of the Anka mine site). The result revealed that 80% passing particle size fractions for feed to the ball mill (F_r, F_t) of both the reference ore and test ore was found to be 663.5 μm and 591 μm, likewise the 80% passing particle size fractions for product from the ball mill (P_r, P_t) of both the reference ore and test ore was found to be 253.73 μm and 236.75 μm respectively. The work index of the Anka (Zamfara State) Manganese Ore was computed to be 14.16 Kwh/ton and the value obtained means that 14.16 Kwh/ton of energy is required to reduce one ton of the Anka (Zamfara State) Manganese ore sample from 80% passing 591 μm to 80% passing 236.75 μm. The work index of the Anka (Zamfara State) Manganese ore was found to be 14.16 Kwh/ton and it falls within the range indicated in literatures as standard which is 10-15.14 Kwh/ton [10,11]. The value was also used in calculating the amount of energy expended (W_t) in grinding the test ore using Bond's equation and was found 3.3984 Kwh was the energy required. It is worth to know that only 1 % of this energy (W_t) was actually used in the ore grinding process; while the rest was converted into noise, heat, etc [11].

4. CONCLUSION

Assessing the grindability behavior of Anka manganese ore towards effective manganese mineral liberation was investigated, This is very important to know the grinding characteristics of theore towards determination of suitable power to be selected for its comminution process and hence selecting suitable design parameters for construction of grinding machine suitable for communition process of studied test ore to its liberation size avoid excess grinding or under grinding. Hence, the work Index and energy expended in grinding of Anka Manganese ore from Anka deposit located in the northern axis of Zamfara state,Nigeria has been computed to be 14.1 kwh/ton and 3.3984 Kwh respectively and its between the recommended values stated in literatures.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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