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EFFECT OF MICROWAVE TREATMENT ON THE GRINDABILIY OF GALENA-SPHALERITE ORES

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ABSTRACT: This work studied the effect of microwave treatment on the grindabiliy of galena-sphalerite ores using iron ore of known work index as the reference ore. The sulphide ore was divided into four portions, three portions were microwaved for 30, 60 and 90 seconds respectively while the fourth portion was used for the controlled experiment. The samples were treated at 750W in 2.45GHz microwave oven. All samples including iron ore were crushed in a jaw crusher and milled in a ball mill. 300g of 600µm samples were weighed for sieve analysis as feed for the reference ore. The work index of the sulphide ore has reduced from 11.22kwhr/sht to 9.38 Kwhr/sht, 8.19kwhr/sht, 7.35kwhr/sht after microwave treatment for 30, 60 and 90 seconds respectively. This means that there had been reduction in energy expended in pulverizing. Anka ore can saved up to 15.4%, 27.0% and 34.3% after 30, 60 and 90seconds treatment respectively when comminuted.
Keywords: Crushing, grinding, grindabiliy, work index

INTRODUCTION

Crushing and grinding is a significant capital and operational cost in many minerals processing plants (Olubambi *et al*., 2009). A limitation to grinding is the generation of fines (from grinding over a long period of time) which could pose problems during processing of sulphide ore. Sulphide ores are always difficult to process because of the complication in their mineralogical associations. Moreover, the complexities in the mineralogical associations of sulphide minerals and the intergrown nature of the constituent mineral usually result in a poor liberation of the associated minerals. When valuable minerals are not freed due to poor liberation pattern they become very difficult to process in the sense that much more energy will be expended and efficient recovery becomes more difficult to attain. Hence, fully determination of comminution parameters relevant to the crushing and milling of these minerals will enhance higher lead and zinc recovery as well as enable proper plant design to take place. Most high-grade deposits of the world have also been depleted which give rise to the need to process low-grade ores. The conventional methods of mineral processing are also no longer effective for the processing of these low-grade ores as different concentrates obtained are of poor quality. As a means for improving the efficiency of conventional grinding circuits, the liberation of minerals and enhancing optimal recovery, the application of microwave irradiation has been observed to be very promising and effective processing for base metal processing. Its applications in mineral processing and extractive metallurgy have been of great and particular research interest for over the past three decades. Despite the significant number of research studies in this area and the potential for achieving highly attractive benefits, there is still no agreement on the mechanism of interaction of microwaves with mineral processing. Microwave technology in mineral processing has been investigated over few decades. Some of its benefits are reported to be cheap, less energy and time consuming and environmentally friendliness. The methods have been explored for mineral ores and interaction between microwave and minerals, differential heating and reduction in comminution energy following comminution reported.1, 2, 3 Specifically for sulphide ores, Kingman *et al*., 2000 reported on the influence of mineralogy on the response of ores to microwave radiation and the reduction in their grinding energy concluding that microwave radiation may cause surface oxidation of sulphide minerals.

This work centres on understanding the effects of microwave pre-treatment on grindability of the sulphide from Anka 12º6'30"N 5º 58'00" in Nigeria. However, any specific work that centered on evaluating the capacity of microwave technology in enhancing processing of galena-sphalerite from Anka sulphide deposit in Nigeria has not been reported in the literature. The trust for this work is that few works available in literature were carried out by Olubambi *et al.,* 2007a and Waziri and Andrews 2014. Olubambi *et al* 2007 centers only on the influence of microwave irradiation on heating characteristics, breakage response, mineralogy and mechanism of dissolution in sulphuric acid and hydrochloric acid, while Waziri 2014 centers on gastric bioaccessibility of lead in soils and sediments from villages in the Anka area which has been adversely affected by artisanal mining of gold from lead-rich ores. The aim of this work is to investigate the effect of the application of microwave irradiation on the grindability of galena-sphalerite occurring in Anka area of north-western Nigeria. The reference ore used for this work is iron ore obtained from Itakpe Nigeria. The method used for this work is the Berry and Bruce Method (1966) which requires the use of reference ore of known grindability.

EXPERIMENTAL PROCEDURE

The samples form Anka were each divided into four portions, three portions were microwaved for 30, 60 and 90 seconds respectively while the fourth portion was used for the controlled experiment in each case. The samples were treated at 750W in 2.45GHz microwave oven. Samples of iron ore were obtained from Itakpe in kogi State crushed in a jaw crusher and milled in a ball mill with steel ball weighing approximately 2kg. 300g of 600µm samples were weighed for sieve analysis as feed for the reference ore. After which the sample were gathered and returned to the Denver ball mill for 15minutes, the product was then taken and sieve into different sieve size (425µm, 300µm, 150µm, 106µm, 75µm, 53µm) fractions using the automatic sieve shaker for 5minutes. After which the fractions were weighed and the value recorded as "feed" and product respectively. The same procedure was repeated for the test ore (microwave treated and untreated). The net work index of Anka ore was determined by the use of the reference ore of a known grindabiliy.

RESULTS

Bond's third equation stated that:

$$W = \frac{10Wi}{\sqrt{P}} - \frac{10Wi}{\sqrt{F}}$$

$$Wr = W_t = W_{ir}\left[\frac{10}{\sqrt{p_r}} - \frac{10}{\sqrt{F_r}}\right] = W_{it}\left[\frac{10}{\sqrt{Pt}} - \frac{10}{\sqrt{F_t}}\right] = \frac{10}{\sqrt{p_r}} - \frac{10}{\sqrt{F_r}}$$

$$Wit = Wir\left[\frac{10}{\sqrt{p_r}} - \frac{10}{\sqrt{F_r}}\right] \Big/ \left[\frac{10}{\sqrt{Pt}} - \frac{10}{\sqrt{F_t}}\right]$$

Where,

Wir = work index of the reference ore
Wit = work index of test ore
Pr = the diameter of the reference ore product 80% of which passes through 100 µm aperture
Pt = the diameter of the test ore product 80% of which passes 100 µm aperture
Fr = the diameter of the reference ore feed 80% of which passes through 100 µm aperture
Ft = the diameter of the test ore feed, 80% of which passes through 100 µm aperture
Wr = work input in kilowatt hour/short ton for reference ore
Wt = work input in kilowatt hour/short ton for test ore.

Table 1: Sieve analysis of the feed to ball mill of reference ore

Sieve range	Normal Aperture	Weight Retained	% Weight Retained	Cum % Weight Retained	Cum %Weight Passing
+425	425	116.77	38.92	38.92	61.08
-425+300	300	47.04	15.68	54.60	45.40
-300+150	150	80.70	26.90	81.50	18.50
-150+106	106	22.30	7.43	88.93	11.07
-106+75	75	13.82	4.61	93.54	6.46
-75+53	53	7.90	2.63	96.17	3.83
-53	-53	11.46	3.82	99.99	0.01

Feed of reference ore
If 106µm = 11.07%
xµm = 80%
80% Passing = 766.03µm

Table 2: Sieve analysis of product to ball mill of the reference ore

Sieve range	Normal Aperture	Weight Retained	% Weight Retained	Cum % Weight Retained	Cum %Weight Passing
+425	425	85.91	28.64	28.64	71.36
-425+300	300	47.06	15.69	44.33	55.67
-300+150	150	95.46	31.82	76.15	23.85
-150+106	106	28.01	9.34	85.49	14.51
-106+75	75	17.39	5.80	91.29	8.71
-75+53	53	10.79	3.59	94.88	5.12
-53	-53	15.37	5.12	100	0.00

Product of reference ore
If 106µm = 14.5%
xµm = 80%
80% Passing = 584.42µm

Table 3: Sieve analysis of performed on the feed of the test ore (untreated)

Sieve range	Normal aperture	Weight retained	% weight retained	Cum% weight retained	Cum% weight passing
+425	425	171.62	57.20	57.20	42.80
-425+300	300	16.23	5.41	62.61	27.39
-300+150	150	25.01	8.34	70.95	29.05
-150+106	106	11.42	3.81	74.76	25.24
-106+75	75	9.24	3.08	77.84	22.16
-75+53	53	10.41	3.47	81.31	18.69
-53	-53	56.07	18.69	100	0.00

If 106µm =25.24
xµm =80%
80% passing =335.97µm

Table 4: Sieve analysis of performed on the product of the test ore (untreated)

Sieve range	Normal aperture	Weight retained	% weight retained	Cum% weight retained	Cum% weight passing
+425	425	214.52	71.50	71.50	28.50
-425+300	300	13.84	4.61	76.11	23.89
-300+150	150	8.23	2.74	78.85	21.15
-150+106	106	6.20	2.07	80.92	19.08
-106+75	75	7.23	2.41	83.33	16.67
-75+53	53	32.01	10.67	94.00	6.00
-53	-53	17.97	5.99	99.99	0.01

If 106µm =19.08
Then, xµm =80%
80% passing =444.44µm

Table 5: Sieve analysis of feed to ball mill of the test ore ((Microwaved at 30 sec)

Sieve range	Normal Aperture	Weight Retained	% Weight Retained	Cum % Weight Retained	Cum %Weight Passing
+425	425	181.71	60.57	60.57	39.43
-425+300	300	14.12	4.71	65.28	34.72
-300+150	150	22.90	7.66	72.94	27.06
-150+106	106	11.25	3.75	76.69	23.31
-106+75	75	9.14	3.05	79.74	20.26
-75+53	53	20.23	6.74	86.48	13.52
-53	-53	40.56	13.52	100.00	0.00

Anka feed of test ore at 30 secs
106 = 16.35%
80% Passing= 518.65

Table 6: Sieve analysis of product of ball mill of the test ore ((Microwaved at 30 sec)

Sieve range	Normal Aperture	Weight Retained	% Weight Retained	Cum % Weight Retained	Cum %Weight Passing
+425	425	162.83	54.28	54.28	45.72
-425+300	300	20.10	6.70	60.98	39.02
-300+150	150	33.00	11.00	71.98	28.02
-150+106	106	15.10	5.03	77.01	22.99
-106+75	75	12.06	4.02	81.03	18.97
-75+53	53	14.72	4.91	85.74	14.06
-53	-53	42.19	14.06	100.00	0.00

Anka product of test ore at 30 secs
106 = 23.31%
xμm = 80%
80%= 363.71

Table 7: Sieve analysis of feed to ball mill of the test ore ((Microwaved at 60 sec)

Sieve range	Normal Aperture	Weight Retained	% Weight Retained	Cum % Weight Retained	Cum %Weight Passing
+425	425	221.54	73.85	73.85	26.15
-425+300	300	8.44	2.81	76.66	23.34
-300+150	150	13.74	4.58	81.24	18.76
-150+106	106	7.23	2.41	83.65	16.35
-106+75	75	6.07	2.02	85.67	14.33
-75+53	53	14.34	4.78	90.45	9.55
-53	-53	28.64	9.55	100	0.00

Anka feed of test ore at 60 secs
106 = 22.99%
xμm= 80%
80% =368.86

Table 8: Sieve analysis of performed on the product of the test ore (Microwaved at 60 secs)

Sieve range	Normal Aperture	Weight Retained	% Weight Retained	Cum % Weight Retained	Cum %Weight Passing
+425	425	143.65	47.88	47.88	52.12
-425+300	300	23.58	7.86	55.74	44.26
-300+150	150	39.54	13.13	68.92	31.08
-150+106	106	18.13	6.04	74.96	25.04
-106+75	75	14.64	4.88	79.84	20.16
-75+53	53	15.90	5.30	85.14	14.86
-53	-53	44.56	14.85	99.99	0.01

Anka product of test ore at 60 secs
106 = 32.42%
xµm = 80%
80% passing = 261.57 at 80%

Table 9: Sieve analysis performed on the feed to ball mill of the test ore ((Microwave at 90 sec)

Sieve range	Normal Aperture	Weight Retained	% Weight Retained	Cum % Weight Retained	Cum %Weight Passing
+425	425	79.61	26.54	26.54	73.46
-425+300	300	28.15	9.38	35.92	64.08
-300+150	150	56.77	18.92	54.84	45.16
-150+106	106	27.22	9.09	63.93	36.07
-106+75	75	21.84	7.28	71.21	28.79
-75+53	53	33.85	11.28	82.49	17.51
-53	-53	51.50	17.50	99.99	0.01

Anka Feed of test ore at 90 secs
106 = 25.04%
xµm = 80%
80% passing = 338.66

Table 10: Sieve analysis performed on the product to ball mill of the test ore ((Microwave at 90 sec)

Sieve range	Normal Aperture	Weight Retained	% Weight Retained	Cum % Weight Retained	Cum %Weight Passing
+425	425	114.24	38.08	38.08	61.92
-425+300	300	22.09	7.36	45.44	54.56
-300+150	150	44.42	14.81	60.25	39.75
-150+106	106	21.99	7.33	67.58	32.42
-106+75	75	18.16	6.05	73.63	26.37
-75+53	53	26.07	8.69	82.32	17.68
-53	-53	53.03	17.68	100.00	0.00

Anka product of test ore at 90 secs
106 = 36.07%
xµm = 80%
80% Passing = 235.10

Applying Bond's third equation, the work indices can be determined as follows:

untreated Sample

Ft = 444.44
Fr = 766.03
Pt = 335.97
Pr = 584.42

$$\text{Wit} = \text{Wir}\left[\frac{10}{\sqrt{p_r}} - \frac{10}{\sqrt{F_r}}\right] / \left[\frac{10}{\sqrt{Pt}} - \frac{10}{\sqrt{F_t}}\right]$$

$$\mathbf{15.27}\left|\frac{\mathbf{10}}{\sqrt{\mathbf{584.42}}} - \frac{\mathbf{10}}{\sqrt{\mathbf{766.03}}} / \frac{\mathbf{10}}{\sqrt{335.97}} - \frac{\mathbf{10}}{\sqrt{444.44}}\right|$$

Wit =11.22kwh/sht

Anka Microwave treated (30 sec)

Ft = 518.65
Fr = 766.03
Pt = 363.79
Pr = 584.42

$$\text{Wit} = \text{Wir}\left[\frac{10}{\sqrt{p_r}} - \frac{10}{\sqrt{F_r}}\right] / \left[\frac{10}{\sqrt{Pt}} - \frac{10}{\sqrt{F_t}}\right]$$

$$15.27\left|\frac{10}{\sqrt{584.42}} - \frac{10}{\sqrt{766.03}} / \frac{10}{\sqrt{363.79}} - \frac{10}{\sqrt{518.65}}\right|$$

= 9.39kwh/sh ton

Anka Microwave treated (60 sec)
Ft =368.86
Fr = 766.03
Pt = 261.57

$$\text{Wit} = \text{Wir}\left[\frac{10}{\sqrt{p_r}} - \frac{10}{\sqrt{F_r}}\right] / \left[\frac{10}{\sqrt{Pt}} - \frac{10}{\sqrt{F_t}}\right]$$

$$\mathbf{15.27} = \left|\frac{\mathbf{10}}{\sqrt{\mathbf{584.42}}} - \frac{\mathbf{10}}{\sqrt{\mathbf{766.03}}} / \frac{\mathbf{10}}{\sqrt{\mathbf{261.57}}} - \frac{\mathbf{10}}{\sqrt{\mathbf{368.86}}}\right|$$

= 8.18kwh/sh ton

Anka Microwave treated (90 sec)
Ft =338.66
Fr = 766.03
Pt = 235.1
Pr = 584.42

$$\text{Wit} = \text{Wir}\left[\frac{10}{\sqrt{p_r}} - \frac{10}{\sqrt{F_r}}\right] / \left[\frac{10}{\sqrt{Pt}} - \frac{10}{\sqrt{F_t}}\right]$$

$$\left|\frac{\mathbf{10}}{\sqrt{584.42}} - \frac{\mathbf{10}}{\sqrt{766.03}} / \frac{\mathbf{10}}{\sqrt{235.1}} - \frac{\mathbf{10}}{\sqrt{338.66}}\right|$$

= 7.35kwh/sht ton

DISCUSSION

Effect of microwave treatment on the grindability of sulphide ores table 1-9shows the results of grindabilty test performed on the untreated and microwaved Anka sulphide ore as as Itakpe iron ore (the reference ore). Since grinding refers to ease with which materials can be comminuted and data from grindabilty test are used to evaluate the crushing and grinding efficiency, the data obtained from these tables were used to determine the work indices for each and all the samples. However, Bond work index is employed in determination of the ore grindability. The Bond work index is the comminution parameter that expresses the resistance of the ore to crushing and grinding and numerically equals to the Kilowatt hour per shot ton required to reduce the ore material from the theoretically infinite size to 80% passing 100μm. Work indices for the two deposit as determined by Berry and Bruce method are as follows: the reference ore (Itakpe Iron ore) is 15.27KwHr/sht, The untreated Anka ore is 11.22kwhr/sht Microwaved Anka at 30 seconds is 9.38 Kwhr/sht, Microwaved Anka ore at 60 seconds is 8.19 Kwhr/sht, Microwaved Anka at 90 seconds is 7.35 Kwhr/sht.,

According to Kingman *et al* (2000), reasons for reduction in work index can be because of the mode of application of energy. He also deduced that explanation for the reduction in work index after microwave treatment can be that the major mechanism is likely to be differential heating and therefore expansion of the minerals within minerals matrix. Ores and minerals respond differently to microwave radiation and ore are heated up differently thereby causing differential expansion within the mineral lattice. The different expansion with the mineral lattice will definitely lead to fracture around grain boundary which means that there will also be good liberation of individual mineral.

CONCLUSION

Effect of microwave treatment on the grindabiliy of galena-sphalerite ores. Results obtained shows that

The results of untreated and microwaved treated ore had clearly shown that microwave treatment had significant effect upon the work indices. The work index of the sulphide ore has reduced from 11.22kwhr/sht to 9.38 Kwhr/sht,, 8.19kwhr/sht, 7.35kwhr/sht after Microwave treatment for 30, 60 and 90 seconds respectively. This means that there had been reduction in energy expended in pulverizing. Anka ore can saved up to 15.4%, 27.0%and 34.3% after 30, 60 and 90seconds treatment respectively when comminuted.

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