The Efficacy of using Gravity Concentration Methods in Value Addition to Ajabanoko Iron Ore for use in Nigerian Smelting Plants towards Metallurgical Purposes

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Abstract— *This research work x - rays the use of gravity separation methods – Wifely shaking tabling and Air flotation (Kip Kelly air floating machine) to produce a high iron ore concentrate that could be used in both Blast furnace and Direct Reduced Induction (DRI) operation as a feed towards the production of Nigerian iron and steel. Crude iron ore assaying 40.72%Fe was beneficiated by using dry air floating processing method and wet wilfley shaking tabling process after characterization and the determination of liberation size of the iron ore and grinding of the crude iron ore to this liberation size of -500 + 355µm.The result revealed that the use of Air floating method gave 67.95%Fe, low acid oxide gangue of 7.3%, while Wilfley shaking tabling gave 51.16%Fe, low acid oxide gangue of 18.6%. It does shows that Air float tabling machine met the required standard grade of iron (≥ 65%Fe) content needed as a charge for the furnace operation, while, the assay and recovery obtain of wilfley shaking tabling could not meet the standard requirement for iron and steel production in the country, Nigeria.*

Keywords— Gravity, Separation, Characterization, Liberation. Oxide gangue.

I. INTRODUCTION

Iron ore is known to be a major raw material for the production of iron ingot when smelted in either blast furnace or direct reduced induction furnace (wills, 2006).This is source in its crude form from its deposit on a mining site and does required processing to meet the standard concentration of either 60%Fe in blast furnace or 65%Fe as in direct reduced induction furnace (CSIRO, 2004). In developing the economy of a country, iron and steel industry is one of the greatest efforts toward industrialization (Weiss, 1985). The functional role of iron and steel products in a nation's economy is attributed to their widespread utilization in all facets of life, ranging from production of iron for steel making which are used for automobiles, locomotives, ship, beams used in buildings, furniture, paper, clips, tools, reinforcing rods for concrete, bicycles and thousands of other items encountered in daily life, (Mokwe, 2002).

Nigeria has abundant reserves of iron ore distributed in different parts of the country with the largest concentration in Kogi State (Itakpe mine project, 1977). The ore investigated is from deposit located in the Okene - Kabba - Lokoja triangle which host some other deposits from Kogi State of Nigeria. Most of the iron ore in Nigeria is of low grade and metamorphic banded iron formations (BIFs).The Ajabanoko iron ore belongs to this low grade and banded iron formations (BIFs), they usually occur in metamorphosed folded bands with Precambrian Basement Complex rocks which include low grade metasediments. (Ministry of Mines and Steel Development (MMSD), 2008).

Location and Geology of Ajabanoko Iron ore Deposit

Ajabanoko is the study area for this project which is located at Okene in Kogi state, Nigeria. Ajabanoko iron ore is on longitude 6^0 14' 0''E and latitude 7^0 33'0'' and lies 4.5km Northwest of Itakpe hill (Adebimpe et al., 2014). The Ajabanoko deposit areas falls within the Nigerian Precambrian basement complex, and a suite of crystalline rocks exposed in over nearly half of the country extending west Dahomeyan of Benin Republic and east into Cameroon (Amingu and Ako, 2009). The Ajabanoko area consists of a set of three closely related hills of basement rocks in which some large bands of iron ore occur. The dominant lithologic units of Ajabanoko deposit area are gneiss of migmatite, biotite and granite, ferruginous quartze, granites and pegmatite (Amingu and Ako, 2009).The ferruginous quartzite is the source of the iron ore mineralization in the area (Oladele,1978).

The nature of Ajabanoko iron ore deposit and the associated rocks indicate that they are residual concentrate derived from iron rich sediment, a volcanogenic sedimentary material (National Steel Development Authority, 1976).this then suggested that all the rocks in the area including the high grade metamorphic ones such as the quartzites may have been derived from sedimentary materials which in turn were probably derived from an ancient volcanic source (National Steel Raw Material Exploration Agency, 1994).Four principal ore layers have been identified as the different ore zones (Nnagha,1997). Four thick bands ranging from 1.0 m to 5.0 m in thickness and measuring 1.22 km along strike have been identified in the deposit, and are classified as orebody I, orebody II, Orebody III and orebody IV as shown in Table 1 (National Steel Raw Materials Exploration Agency, 1994). Petrological studies of the ore have revealed four (4) major types of ore composition similar to Itakpe Hill, Itakpe Nigeria: (i) magnetite quartzites (ii) magnetite – hematite quartzites (iii) hematite-magnetite quartzites (iv)hematite - quartzite. The total iron ore reserves in the entire Ajabanoko iron ore deposit is 62.104 million tons (Adebimpe et al., 2014).

Table.1: Parameter of the Main Ore Layer of Ajabanoko Iron Ore Deposit

Ore Layer	Length along strikes (m)	Average thickness (m)	Average Fe_{total}
Orebody I	1100	14.7	40.40
Orebody II	925	10.0	30.30
Orebody III	750	3.6	37.28
Orebody IV	-	4.3	34.04

National Steel Raw Materials Exploration Agency (1994), Adebimpe et el, (2014)

Iron Ore Value Addition

Iron ores are typically classified as high grade at 65%Fe_{total}, medium at 62%-65%Fe_{total} and low grade at 60-62%Fe_{total}. For economy reasons, these low grade iron ore can be beneficiated to meet the standard quality requirement of iron and steel industries, The specification of iron ore for Blast furnace is 63 or 64% Fe_{total}, Direct Reduction and smelting reduction of 67%-69%Fe_{total}. (Wikipedia, 2013).

Iron ore is upgraded to higher iron content through concentration. Iron ore is being beneficiated all round the world to meet the quality requirement of Iron and Steel industries. However, each source of Iron ore has its own peculiar mineralogical characteristics and requires the specific beneficiation and metallurgical treatment to get the best product out of it. The choice of the beneficiation treatment depends on the nature of the gangue present and its association with the ore structure (Itakpe Mines Project, 1977). Basically several techniques such as washing, jigging, magnetic separation, advanced gravity separation and flotation are being employed to enhance the quality of the Iron ore (http://www.minmetandequip.blogspot.com, 2008, MMSD, 2008, http://www.psranawat.org/mettalic/ironore.htm, 2014).

The aim of this research work is to investigate the efficacy of using gravity methods; Wilfley shaking tabling and air floating separation methods to produce iron ore concentrate for use in Nigerian steel plants and to determine the best gravity processing method by considering the grade and recovery of the iron ore produced that could be used as a charge into smelting furnace for the production of iron and steel for metallurgical industries in Nigeria.

II. MATERIAL AND METHODS

Material

Crude iron ore sample used was sourced for, from an iron ore deposit on mining site located in Ajabanoko town in the Okene - Kabba - Lokoja triangle of Kogi state, Nigeria, on longitude 6^0 14' 0''E and latitude 7^0 33'0'' and lies 4.5km Northwest of Itakpe hill ; which also host some other deposits. 50kg of the ore sample was sourced from five (5) different pits on the mines site, with pits A,B,C,D at the four corners of the mining site while the fifth (5^{th}-) pit was dug at the center point of the four other points (sample F). Each pits were dug at 2 meters by 2 meters and 6 meters dip; this was then size reduced from boulder size to between 10-5mm. The samples realized were mixed thoroughly to have homogeneity, before final sample of 50kg that was used for this research work was picked using random sampling methods.

Gravity Separation Methods

5Kg of the crushed -0.5 +0.355mm crude Ajabanoko iron ore was mixed with water in the ratio 1: 4 (Ore: Water) to form slurry and was fed at a feed rate of 50 liters/min. into the deck of wilfley shaking tabling machine tilted at 180^0 (0^0), with the middling repeated, while concentrate and tailings were sun dried after which they were properly mixed separately and sampled using random sampling method for analysis with results shown on Table 2-6. Another 5kg of crushed crude Ajabanoko iron ore sample was fed dry at 50 kg/min onto Kip Kelly air floating machine deck tilted at an angle of 180^0 (0^0), Air inlet opened at 2mm running at 1500rpm. Concentrate and tailing reported to bucket 1 and 6 respectively; samples from these buckets were analyzed using ED- XRF Spectrometer at the Instrumental laboratory of the National Metallurgical Development Centre, Jos. (Tables 2-6).

III. RESULTS AND DISCUSSION

Results

Results of all the experiments carried out at the course of this research work were presented in Tables 2 – 6.

Table.2: Results obtained from Gravity separation methods

METHODS	CHARGE (Kg)	CONCENTRATE (Kg)	MIDDLING (Kg)	TAILING (Kg)
WIFELY SHAKING TABLE	5.00	3.30	0.70	0.80
AIR FLOATING	5.00	2.20	0.05	1.70

Table.3: Chemical analysis of Crude Ajabanoko Iron ore

S/N	**Sample**	**Al_2O_3**	**SiO_2**	**P_2O_5**	**SO_2**	**K_2O**	**CaO**	**TiO_2**	**Cr_2O_5**	**MnO**	**Fe_2O_3**	**Fe_T**	**CuO**	**MgO**
1	**Crude**	BDL	34.4	BDL	BDL	0.08	0.23	0.06	0.2	BDL	58.22	40.72	0.04	BDL

Table.4: Result of the Chemical Analysis of Ajabanoko Iron ore Processed Using Wilfley Shaking Method

S/N	**Sample**	**Al_2O_3**	**SiO_2**	**P_2O_5**	**SO_2**	**K_2O**	**CaO**	**TiO_2**	**Cr_2O_5**	**MnO**	**Fe_2O_3**	**Fe_T**	**CuO**	**MgO**
1	Conc	0.62	22.38	BDL	0.04	0.05	0.2	0.03	0.18	0.01	73.78	51.6	0.06	0.14
2	Tailing	0.77	72.05	BDL	BDL	0.34	0.68	0.06	0.18	0.04	22.19	15.52	0.06	0.15

Table.5: Result of the Chemical Analysis of Ajabanoko Iron ore Processed using Air float Separation Method.

S/N	Sample	**Al_2O_3**	**SiO_2**	**P_2O_5**	**SO_2**	**K_2O**	**CaO**	**TiO_2**	**Cr_2O_5**	**MnO**	**Fe_2O_3**	**Fe_T**	**CuO**	**Mgo**
1.	Conc	0.54	1.88	0.16	BDL	0.03	0.10	0.09	0.19	0.008	97.16	67.95	0.02	0.20
2.	Tailing	1.00	30.60	BDL	BDL	0.12	0.21	0.06	0.19	0.06	62.82	43.94	0.07	0.22

Table.6: Theoretical Recovery of Gravity Separator

EQUIPMENT	**CHARGE (kg)**	**Concentrate (Kg)**	**Assay**	**Recovery Cc/Ff X100%**
Wifely Shaking Conc.	5.00	3.30	51.60	83.63
Wifely Shaking Tailing	5.00	0.80	15.52	6.10
Air Float Conc.	5.00	2.50	67.95	85.44
Air Floating Tailings	5.00	1.10	43.94	23.74

Discussion

Tables 2-6 present the results obtained during the research work. Table 2 – 6 is the weight and assay of the crude, assay of the Gravity Separation studies product using Wilfley Shaking Tabling and Kip Kelly Air floating methods. Table 2 shows that the crude iron ore assays 40.72%Fe total, which is quite low to serve as a feed towards charging into either furnaces, with no alumina, phosphorous and Sulphur. The silica content of 34.4%SiO_2 which according to Wills, 2006 is too high and could be the major source of impurity which hinders the iron from being acceptable as a feed towards the production of iron and steel in these furnaces. This silica therefore was reduced via suitable processing methods to increase the quality of the iron ore under study. While Tables 2, 4 and 6 gave results of Wilfley shaking tabling with concentrate weight of 3.30kg and tailing 0.80kg assaying 51.60%Fe and 15.52%Fe respectively and recovery of 83.63% and 6.10% respectively. This shows an improvement in the quality of iron ore produced compared with the crude, but failed to meet the standard quality of iron ore required for blast furnace charge of 60-65%Fe. Tables 2, 5 and 6 gave the result of using Kip Kelly Air floating method with concentrate weight of 2.20kg and tailings of 1.70kg assaying 67.95%Fe and 43.94%Fe respectively and recovery of 85.44% and 23.74 respectively. This gave a better quality iron ore concentrate that met the required standard of above 65%Fe needed as a charge for iron and steel production in either of the furnaces. This shows clearly that the use of Air flotation method to process Ajabanoko iron ore gave a better result and added more value in terms of iron ore assay (67.95%Fe) with recovery of 85.44% as against that of Wilfley shaking tabling with iron ore assay of 51.60%Fe and recovery 83.63%.

IV. CONCLUSION

In conclusion, the value addition to Ajabanoko iron ore via mineral processing was more successful using Air floatation method rather than Wilfley shaking tabling and as such the latter should be chosen ahead of the other. In addition to this; the iron ore produced using air floatation method met the minimum standard of 65%Fe (%iron) needed as charge in both Ajaokuta and Delta steel complexes for the production of Nigerian Iron and Steel.

V. ACKNOWLEDGMENT

The authors acknowledged the management of the National Metallurgical Development Centre, Jos for given us a chance towards carrying out this bench work in their Mineral Beneficiation Pilot Plant and the use of mineral Instrumental laboratory for same. The Research and Technical staff of the establishment were all appreciated.

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