BENEFICIATION OF MURO IRON ORE DEPOSIT BY MAGNETIC SEPARATION METHOD

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ABSTRACT
In this work the possibility of up-grading a sample of iron ore from Muro iron ore deposit to a concentrate suitable for the production of pig iron using the conventional blast furnace process by dry magnetic separation method was investigated. The Muro iron ore deposit is located in Toto local Government area of Nasarawa State. The Iron ore deposit has an estimated reserve of 3.8 millions tonnes scattered over three different locations with an average iron content of 31.6% (Fe) and silica content of 56.57% (SiO₂). The concentration tests were carried out using a laboratory scale magnetic separation machine at a magnetic field intensity of 20 ampere per meter. The result of the concentration test s revealed that, an optimum grade of 57.19%Fe and recovery of 81.86% at particle size fraction of -80 + 63µm and with least value of 8.26% silica content could be attained. Based on the results obtained the concentrate produced might be used in iron production using the Blast furnace process route. However the economics of the process needs to be looked into as grinding the bulk of the ore directly to -80+63µm may be very expensive in the case of iron ore being a low priced commodity in the international market.

SIGNIFICANCE: The work has shown that, Muro iron ore deposit can be beneficiated using magnetic separation technique to a concentrate grade suitable for the production of pig iron by the conventional blast-furnace process.

Keywords: Beneficiation, Muro iron ore, Magnetic separation, Blast furnace process.

1.0 INTRODUCTION
Iron and Steel industries are the foundation for the technological take-off, economic self reliance and advancement of a Country. In realization of this fact the Federal government of Nigeria in 1971 launched the Country into a new era of Iron and Steel technology by the establishment of the Delta and Ajaokuta steel projects. Although the establishment of the projects was a good and welcomed idea the Ajaokuta project never got completed because of so many obvious Nigerian factors. Only Delta steel project was commissioned but was closed a few years later after it has been handed over to Nigerian Managers. One of the reasons for the closure of the Delta Steel plant was lack of continuous of supply raw material (Iron concentrate) locally because at conception it was to be supplied with high grade iron ore concentrate from Guinea, Brazil and Liberia. The high cost of importing the raw material in terms of Foreign exchange and continuous devaluation of the Naira made it impossible and uneconomical for the plant to be operated (Adiewere et al, 1998). Even with the present arrangement the Government had gone into for the Ajaokuta, and Delta Steel plants the same problem of sourcing and continuous supply of the basic and important raw materials (Iron ore concentrate and coking coal) locally will prevent continuous flow of liquid steel. This is because the Itakpe Iron ore deposit estimated at 200 millions tonnes that can be upgraded and supplied to Ajaokuta steel plants Oloche et al (1995), can only last for a few years. Presently, the plant cannot meet the demand of Ajaokuta and Delta steel plants in terms of quantity and quality. Therefore the viability of any iron and steel plant is dependent on the availability and long time continuous supply of the basic raw material(iron ore concentrate). Also because the iron ores are bulky there is the need to source them locally, not only to reduce dependence on the imported source but scarce foreign exchange will also be saved.

Fortunately, Nigeria is blessed with large reserves of iron ore deposits concentrated along kogi - Benue trough. One of the deposits is the Agbaja iron ore deposit, the largest in Nigeria (over 1 Billion tonnes in reserve) with extremely fine grained texture hence has to be ground to -5um in order to achieve a reasonable degree of liberation. However, at this extremely fine size, most conventional beneficiation techniques, such as froth flotation, gravity concentration cannot be used to recover the fine iron oxides. Economically, to grind the ore to that size will not be wise in case of iron ore because of its low market value coupled with its very high
phosphorus content which has discouraged its utilization to date (Uwadiale, 1989). In fact for each type of process for the production of iron and steel there are specific requirements in the nature of raw materials. For example while the conventional Blast furnace route for iron production requires iron ore sinter produced from a concentrate of at least 63% Fe and coal that must be coking to produce coke, the Midrex Direct Reduction process must be provided with a higher grade iron ore (at least 67% Fe) for the production of direct reduced iron using either non-coking coal or natural gases (Garba et al, 2004). Table 1 gives a summary of the specific requirements of raw materials for iron production by the blast furnace (Ajaokuta) and direct reduction (Delta) processes respectively.

Because of the importance of iron and steel to our national development, it has become very necessary to look at the possibility of beneficiating low grade locally available iron ore deposits for use as feedstock to the indigenous iron and steel plants located at Delta and Ajaokuta. This prompts this work on "up-grading of Muro iron ore so as to produce a concentrate that can be used in the conventional blast furnace iron making process by magnetic separation method". The Muro iron ore deposit is located at three (3) different areas in the vicinity of Muro town within the Toto Local Government Area of Nasarawa State. The deposit was discovered by the Nigerian Geological Survey department and has estimated ore reserves of about 3.8 million tonnes. The iron ore lumps which are enter layered with quartzite are generally medium to fine grained. The chemical and mineralogical characteristics of the ore have been determined by (Dungka et al, 1998). The chemical and mineralogical characteristics of an ore are very important parameters, because from these characteristics the assay as well as the amount and type of impurities, the major, minor and trace minerals, the qualities of each mineral and also the grain size distribution of the minerals of economic importance associated with the ore are determined. These parameters, when determined, are used in the determination of liberation sizes of the individual grains of minerals and in the development of a process flow sheet for the ore (Yaro, 1997).

1.1 Theoretical Consideration

1.1.1 Basic principle of magnetic separation technique

Magnetic method of separation of minerals exploits the differences in magnetic properties between the constituent minerals in the ore. The concentration is achieved by passing a mixture of liberated mineral particles through a non-homogenous magnetic field resulting in the preferential retention or deflection of the magnetisable mineral particles (Corrans, 1980).

The basic principle of magnetic separation involves exposing the liberated minerals to a magnetic field in which they are acted upon by several external forces with a dominant magnetic force. The separation of minerals depends upon their motion in response to the dominant magnetic force and other competing forces namely, Gravitational, Frictional, Inertia and Centrifugal. For example in the case of the separation of ferromagnetic minerals, the magnetic force acting on the particles will be greater than the sum of all other competing forces as a result of which the minerals will be attracted to the magnet. However for non-magnetic minerals, the magnetic force will be smaller than the sum of all other competing forces and the minerals will be repelled away from the magnetic field (Oberfen, 1987). Figure 1 illustrates the basic principle of magnetic separation showing the number of forces that act on mineral when placed in a magnetic separation machine and how the separation is effected. For the purpose of magnetic separation, minerals are classified into three main groups based on their response to a magnetic field. The Ferromagnetic minerals are strongly attracted by a magnetic field and can sometimes retain the magnetism even when removed from the field. Paramagnetic minerals are weakly attracted by a magnetic field and the diamagnetic minerals are repelled along the lines of magnetic force to a point where the magnetic field is negligible (Dwight, 1967).

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2.0 MATERIALS AND METHODS

2.1 Materials
The sample of the Muro Iron ore used in this test was obtained from Toto Local Government Area of Nasarawa State, Nigeria. Three samples were collected from three different locations and then bulked together. The blend has an average iron content of 31.6% Fe and 56.57% SiO₂.

2.2 Methods
The blend sample of the iron ore was ground using a laboratory pulverizing grinding machine and sized into various size fractions from +355μm to -80 + 63μm using an electric sieve shaking machine. The various sieve fractions produced were subjected to magnetic separation test using a laboratory magnetic separation machine at a magnetic field intensity of 20 amperes meter, after which two products (concentrates and tailings) were collected for each size fraction from the machine. The concentrates and tailings of each size fraction were weighed and analyzed for iron and silica content using Atomic Absorption Spectrometer (AAS).

3.0 RESULTS AND DISCUSSION

3.1 Results
The results of the separation test carried out using dry magnetic separation technique are given in Table 2. In Figure is given the variation of Grade and Recovery of the concentrate with particle size and Figure 3 shows the variation of iron and silica Recoveries in the concentrate with particle size.

3.2 Discussion
The result in Table 2 gives the assay of iron and silica determined for each concentrate and tailing from each size fraction and the percentage recoveries of the iron and silica. From the result it can be seen that the assay of iron in the concentrates increases with decrease in particle size which shows that the iron bearing mineral (Fe₂O₃) is being liberated from the gangue (silica) as the ore was ground finer. With particle size fraction -80 + 63μm having the highest Iron assay value of 57.19% at a recovery of 81.86% and with the least silica content of 8.26%.

However, a reverse trend could be observed in the case of silica content in the tailings as it increases with decrease in particle size. The particle size fraction (-80 + 63μm) has the highest value of 55.38% (SiO₂) and least...
value of 8.25% Fe in the tailings which implies that, optimum separation efficiency might have been achieved at this size fraction (-80 + 63 μm) since at this size fraction the concentrate produced contains the least amount of the gangue 8.26% SiO₂ and highest assay of the valuable (57.19% Fe). The highest percentage of iron and the least percentage of SiO₂ in the concentrate of this fraction (-80 + 63μm) means that optimum liberation of the iron bearing minerals from the gangue might have been achieved at this size fraction.

The results obtained of the concentration test using dry magnetic separation method on this ore is in agreement with a similar work done on the ore by Mathur (1983), who conducted a straight magnetic separation test on a few mixed samples after grinding and produced a concentrate assaying nearly 55% Fe. Even though the size fraction at which the test was carried was not indicated.

In Table 2, it can be observed that an approximately inverse relationship between recovery and grade does exist, so any attempt to improve on the grade of the concentrate, the losses to the tailings will be higher and the recovery will be low. Also in Figure 2 it can be seen that as the particle size decreases the recovery decreases while the grade of the concentrate increases this is because at finer particle sizes the iron bearing minerals are completely liberated from the gangue (silica). However, any attempt to go for higher recovery, there will be more gangue in the concentrate and the grade of concentrate will decrease.

It is always impossible to say which combination of grade and recovery is the best for a particular separation technique as concentrate grade and recovery are the widely used parameters in assessing metallurgical performance and also determine the economic returns (Metallurgical efficiency) of any mineral processing plant. Because of their inverse relationship, any attempt to increase one results in the decrease of the other. However in practice, the plant operators always try to improve the two parameters by a process called optimization. In optimization, the position of the grade/recovery curve is shifted to the right such that there is simultaneous increase in both concentrate grade and recovery while the inverse relationship between concentrate grade and recovery is still maintained.

In fact concentrate grade and recovery, used simultaneously, are the most widely accepted parameters for assessing metallurgical (not economic) performance. However, there is a problem in quantitatively assessing the technical performance of a concentration process whenever the results of two similar test runs are compared. In situations where both the grade and recovery are greater for one case than the other, the choice is simple. However, if the result of one test has a higher grade but a lower recovery than the other, the choice is no longer obvious. There have been many attempts to combine recovery and concentrate grade into a single index defining the metallurgical efficiency of a separation process. For example, the Separation Efficiency (S.E) of a concentration process has been proposed by Sroboda, (1987) as

\[ S.E = Rm - Rg \]

Where

\[ Rm = \% \text{ recovery of the valuable into the concentrate} \]
\[ Rg = \% \text{ recovery of the gangue into the concentrate} \]

So as Rm increases and Rg decreases the difference between the two increases hence the value of S.E the Separation Efficiency increases. Figure 3 gives the variation of iron and silica recovery in the concentrate with particle size. From this Figure, it can be seen that as the particle size decreases, the recovery of the valuable mineral into the concentrate increases while that of the non-valuable mineral (silica) decreases, this means that there is an increase in the Separation Efficiency(SE) of the Magnetic separation process with decrease in particle size.

4.0 CONCLUSION

Based on the results of the present investigation on the up-grading of Muro iron ore deposit using dry magnetic separation method it could be concluded that the iron ore can be up-graded using straight magnetic separation technique to produce a concentrate grade that can be used for the production of pig iron using the conventional Blast furnace process. However, the economics of this route which involves grinding the Run-of-Mine ore straight to ~80 + 63μm size fraction before separation needs to be carefully considered as iron ore concentrates are low priced commodity in the international market and grinding the bulk of the ore to this size fraction will consume a lot of energy.
REFERENCES


Table 1: The Specifications for Sinter and Pellet Production for the Conventional Blast Furnace and Direct Reduction Processes

<table>
<thead>
<tr>
<th>Process/ Parameter</th>
<th>Fe&lt;sub&gt;total&lt;/sub&gt; %</th>
<th>Fe&lt;sub&gt;2&lt;/sub&gt;O&lt;sub&gt;3&lt;/sub&gt; %</th>
<th>FeO %</th>
<th>CaO %</th>
<th>Gangue (SiO&lt;sub&gt;2&lt;/sub&gt;+Al&lt;sub&gt;2&lt;/sub&gt;O&lt;sub&gt;3&lt;/sub&gt;) %</th>
<th>MgO %</th>
<th>P %</th>
<th>S %</th>
<th>LOI %</th>
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<tbody>
<tr>
<td>Blast Furnace Process</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Concentrate For sinter Production</td>
<td>63.0</td>
<td>88.9</td>
<td>1.0</td>
<td>0.15</td>
<td>9.60</td>
<td>Trace</td>
<td></td>
<td></td>
<td>0.21</td>
</tr>
<tr>
<td>Lump for Direct Charging</td>
<td>54.82</td>
<td>74.5</td>
<td>3.5</td>
<td>4.0</td>
<td>12.0</td>
<td>1.0</td>
<td>0.044</td>
<td>0.08</td>
<td>4.4</td>
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<td>Direct Reduction Process</td>
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<td></td>
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<td></td>
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<tr>
<td>Super Concentrate For pellet production</td>
<td>66.80 Minimum</td>
<td>95.5 minimum</td>
<td>0.5</td>
<td>0.1</td>
<td>&lt;2.70</td>
<td>0.1</td>
<td>0.003 Max</td>
<td>0.003 Max</td>
<td>1.20 Max</td>
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### Table 2: Results of the Magnetic Separation Test

<table>
<thead>
<tr>
<th>Sieve Size Fraction μm</th>
<th>Weight of Feed (g)</th>
<th>Assay of Feed %</th>
<th>Concentrates</th>
<th>Tailings</th>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Weight (g)</td>
<td>Assay %</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>FeT</td>
<td>SiO₂</td>
</tr>
<tr>
<td>+335</td>
<td>588.354</td>
<td>31.87</td>
<td>54.40</td>
<td>553.253</td>
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<tr>
<td>-335 +250</td>
<td>768.639</td>
<td>31.69</td>
<td>54.40</td>
<td>689.743</td>
</tr>
<tr>
<td>-250 +180</td>
<td>683.584</td>
<td>31.62</td>
<td>58.40</td>
<td>551.265</td>
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<td>-180 + 125</td>
<td>618.768</td>
<td>31.57</td>
<td>57.80</td>
<td>430.166</td>
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<td>-100 + 90</td>
<td>230.291</td>
<td>32.70</td>
<td>55.57</td>
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<td>-90 + 80</td>
<td>249.667</td>
<td>35.62</td>
<td>55.58</td>
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<td>-80 + 63</td>
<td>306.847</td>
<td>40.35</td>
<td>50.21</td>
<td>177.213</td>
</tr>
</tbody>
</table>

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Figure 2: Variation of Grade and Recovery with Particle Size Fraction

Figure 3: Variation of Iron and Silica Recovery in the Concentrate with Particle Size