CHEMICAL AND PHYSICAL CHARACTERISTICS OF AGBAJA AND ITAKPE IRON ORE SINTER BLENDS

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ABSTRACT

The chemical and physical characteristics of sinter blends produced from Agbaja iron ore concentrate of high phosphorus and low silica and Itakpe iron ore concentrate of low phosphorus and high silica were determined in this work. The two ores were concentrated using conventional beneficiation techniques and then blended in the ratios of 10-70% Agbaja and 90-30% Itakpe. The blends were mixed with coke breeze, limestone and moisture to produce fluxed sinters. The physical and chemical characteristics of the produced sinters vis-a-vis abrasion resistance, shatter index, tumbler index, reducibility, reduction decrepitating and chemical composition were determined. The results obtained revealed that, the physical and chemical properties of the produced sinters compared favorable with minimum blast furnace specifications. However, the sinter with 10% Agbaja and 90% Itakpe possesses physical and chemical properties that are close to the specified properties of sinter for use in the blast furnace for Pig iron production. Therefore, sinter blend with 10% Agbaja and 90% Itakpe iron concentrates can be recommended for use in blast furnace for production of pig iron.

SIGNIFICANCE:
This work has shown that, Agbaja iron ore can be blended with Itakpe and used in the production of sinters suitable for the production of Pig iron by the conventional blast furnace route.

KEYWORDS: Agbaja and Itakpe, Chemical and Physical Properties, Iron Ore Concentrates, Sinter Blends.

1.0 INTRODUCTION

The survival of any industry, depend on raw materials input and continuous supply of these raw materials in large quantity and of good quality must be assured. Even though Nigeria is blessed with large quantities of iron ore deposits of over three billion metric tonnes, these deposits cannot be used directly in pig iron production without beneficiation because some of them are low grade and contain impurities, which can be detrimental to the properties of the steels to be produced. Some researches have already been carried out on the beneficiation of some of these ores for use for pig iron production by Adigwe, (1973), Edah (1974), and Oloche et al, (1995).

Only one of the deposits in the proven reserves is currently been exploited and processed, that is the Itakpe iron ore deposit. This deposit has an estimated reserve of about 200 millions tonnes and has been earmarked to supply to Ajaokuta and Delta steel plants. However, this deposit based on the designed requirement of the Ajaokuta plant will only last for 25 years (Adigwe, 1983). This is grossly inadequate for the establishment of a formidable foundation for a well- projected and integrated iron and steel plants. Also the Agbaja iron ore deposit, even though the largest iron ore deposit in Nigeria estimated at over 1 billion tonnes has a very high phosphorous content in addition to its extremely fine grained texture and this has discouraged its utilization to date (BRGReport, 1983 and Adeleye,1964).

With these attendant problems it has become very necessary to find ways of using this vast deposit of iron ore and the most probable way to utilize the large quantity of iron ore is by blending with other iron ores with lower phosphorous content. Therefore the objective of this work is to blend Itakpe super concentrate of low phosphorous with the Agbaja concentrate so as to produce a sinter mix that can serve as feed to blast furnace for pig iron production.
Even though majority of blast furnaces use sinters or pellets as feed to the burden. Sinters are the most important and suitable of these two types of feeds (Khomich and Toporenko, 1978). The process of sintering comprises a high temperature-treatment (above 1000°C) of iron fines on a moving grate, blended with fluxes and coke breeze (finely divided coke) to form hard lumps or iron-rich material suitable for use as blast furnace feed (Williams 1983). In iron ore sintering, the aim is always to produce strong but porous agglomerate from a sandy uncompacted mass. Tulpkary et al., (1998) noted that in order to obtain smooth and hard (rapid driving) operation the burden charged in the furnace, sinters should ideally posses the following physical and chemical properties.

They are:

**Physical properties**
1. A close size range with minimum of fines.
2. An ability to withstand the physical stresses incurred on being transported to the furnace, charged to the hopper and the bells and, finally into the furnace.
4. An ability to withstand mild reducing condition at lower temperature without breaking.
5. A good bulk reducibility so as to obtain closed equilibrium conditions between solid and gas phases in the stack.
7. A high softening tendency with a narrow temperature range of fusion.

**Chemical properties**
1. A high percentage of iron to gangue ratio.
2. A low percentage of silica, alumina and a low alumina to silica ratio.
3. Good overall chemistry of the burden to ensure adequate desulphurization of metal and absorption of coke ash in slag. Also an excellent chemistry to ensure clean slag and metal separation at minimum temperature and free flow of both slag and metal from the furnace on opening the corresponding outlets (Wild, 1953) and (Wegman, 1984).

In addition, sintering is carried out to improve size grading and reducibility of iron ore concentrate to avoid wasting of fines. Reduce the quantity of coke used in the blast furnace and lastly to use up waste materials from blast furnace flue dust.

### 2.0 MATERIALS AND METHODS

#### 2.2 Materials
A total of 15 kg of Agbaja and Itakpe iron ore concentrate were sourced from National Metallurgical Development Center, Jos while calcined lime and coke breeze were collected from Ajaokuta stockyard.. The chemical composition of each raw material is given in Table 1.

#### 2.3 Methods
Ten (10) sinter blends containing 10, 15, 20, 25, 30, 35, 40, 50, 60, 70% Agbaja and the balance Itakpe concentrate were prepared. The ground concentrates were mixed with calcined lime and coke breeze and later hydrated with water. The quantity of lime added to each blend was calculated so that each blend will have a basicity range of 2.4 to 2.7.

The mixture was charged into sinter pot and ignited while ensuring that the bed was not too compacted to hinder the flow of air. The following physical and chemical properties of fluxed sinters were determined: Abrasion Index Value (AIV), Shatter Index Value (SIV), Tumbler Index Value (TIV), Reducibility Index Value (RIV), Reduction Decrepitation Index Value (RDIV) and compositional analysis. The results obtained are given in Table 2 and 3 respectively.

### 3.0 RESULTS AND DISCUSSION

#### 3.1 Results
The results of the tests and analysis carried out are given in Tables 2, 3 and Figure 1 respectively.

#### 3.2 Discussion
The results of the variation of the abrasion index with blend ratio are presented in Table 2. From these results it can be seen that the abrasion index values increase as the ratio of Agbaja iron ore concentrate in the blend increases. This increase is probably due to the texture of the Agbaja iron ore (liberation size of 5μm) resulting in the
production of much finer sinters as its proportion increases in the sinters. The finer sinters produced resulted in the assimilation of iron oxide and increase in the recrystallization of secondary phases. However, the values obtained for all the blends are within the recommended range for blast furnace requirements of 4.50 – 10.50. Also the blend with the ratio of 10% to 90% Agbaja to Itakpe has a minimum value of abrasion index hence the most suitable because the lower the abrasion index value the stronger the ability of the sinter to withstand degradation during movement in plant and in the furnace.

From these results (Table 2) it can also be seen that the shatter index values decrease with increase in the ratio of Agbaja iron ore concentrate in the blend. The decrease in the values was probably due to formation and distribution of calcium silicate in iron bearing matrix phases as observed by Tupkary et al., (1998). Shatter index is a measure of the resistance of the sinter to impact and is an indication of the degree of fracture the sinter is likely to undergo during charging into the blast furnace. 10% Agbaja iron ore concentrate in the blends has met the minimum requirements for shatter index. However, the higher the shatter index value the stronger the ability of sinters to withstand impact during movement in the furnace.

In the same Table 2, it is clear that the tumbler values decrease as the ratio of Agbaja iron ore concentrate was increased. It may be probably due to the weak and low porous sinters produce as a result of the inability of hematite to transform to magnetite, rather precipitation of wustite occurred. From the results obtained, it can be seen that blends with 10-15% Agbaja have the highest values of tumbler indexes which are within the specified range 77-88 Sofremines (2001). Higher the tumbler index value means better ability of the sinter to withstand disintegration during storage in the bins.

Similarly in the same results (Table2), the reducibility index value decrease as the blend ratio increase. This may be probably due to low porosity of the sinters produced because as the proportion of Agbaja iron concentrate increases the amount of fines in the sinter increased. Similar observations have been reported by Wegman, (1984) and Williams, (1983) and attributed the decrease in reducibility with increase in the proportion of fine material in the sinter to be as a result of the reduction in the surface area of voids accessible to the reducing gases. The decrease in reducibility may also due to the presence of some minerals such as fayalite, Ca-olivines, ferruginous glasses and brown millerite present whose melting temperatures are higher than the sintering temperature However From the results, it can be seen that sinter blends with 10 – 15% Agbaja have values of reducibility index which can be compared favourably with the specified minimum of 69-73.

In the case of the reduction decrepitation it also decreases as the blend ratio increases. As the proportion of Agbaja iron ore concentrate increase the reduction decrepitation index values decrease. With sinter blends having 10-25% Agbaja iron ore concentrate meeting the specified minimum standard of 29.00-35.00 (Ispat, (2004). It should be noted that the lower the values of the decrepitation index, the better the sinter and the easier its reduction at the stack without decrepitating. Figure 1 shows the variation of all the five parameters with increase in Agbaja iron ore in the sinter blend. From this Figure it can be seen that three out of the five parameters determined (SIV, TIV and RIV) decrease with increase in the Agbaja iron ore in the sinter blend while two (RDIV and AIV) increased.
The chemical compositions of the produced sinter blends are given in Table 3. The major consideration in the selection of sinters for blast furnace operation is the percentage composition of Fe, CaO, Al₂O₃, SiO₂, P and the basicity (CaO/SiO₂) (Wild, 1953) and (Wegman, 1984). While it is desirable to have high iron content, basic gangue should be moderate to limit the amount of fluxing agents.

From the results obtained it can be seen that the iron content decreased from 65.45 to 60.50%, lime from 8.22 to 3.47%. However, Alumina increases from 1.32 to 4.12%, silica from 5.61 to 7.86%. Also the phosphorous content increases progressively from 0.09 to 0.41% while the basicity decreases as the blend ratio of Agbaja iron concentrate increases. Considering the phosphorus content, only the first two blends whose phosphorous content is less than or equal to 0.12% met the blast furnace specification for pig iron production as pointed out by Tupkary et al., (1998). However, increasing the percentage of Agbaja in the blend will lead to high phosphorus pig iron, which may not be economical to steel makers.

4.0 CONCLUSION

From the results of both the physical tests and chemical analyses carried out on the sinters produced, the following conclusions may be drawn:

1) Up to 10% of Agbaja concentrate could be blended with 90% of Itakpe concentrate to produce sinters that meet most of the specifications required of sinters for use in Pig iron production via the blast furnace route.

2) That the large deposit of Agbaja Iron ore can be utilized by blending with Itakpe iron ore thereby increasing the source of iron ore for the Nation’s Iron and Steel industries

3) The pig iron produced could be refined to get the required steels using any method that can handle medium phosphorus pig iron for example Kaldor Steel making process.
REFERENCES

Table 1: Chemical analyses of the Raw Materials Used.

<table>
<thead>
<tr>
<th>Constituents</th>
<th>Tot Fe (%)</th>
<th>SiO₂ (%)</th>
<th>CaO (%)</th>
<th>Al₂O₃ (%)</th>
<th>TiO₂ (%)</th>
<th>MgO (%)</th>
<th>P (%)</th>
<th>Mn (%)</th>
<th>S (%)</th>
<th>Co₂ (%)</th>
<th>H₂O (%)</th>
<th>C (%)</th>
<th>Moisture Content(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agbaja Concentrate</td>
<td>58.02</td>
<td>10.89</td>
<td>1.21</td>
<td>9.60</td>
<td>0.37</td>
<td>0.54</td>
<td>1.43</td>
<td>0.18</td>
<td>0.12</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Itakpe concentrate</td>
<td>66.28</td>
<td>5.50</td>
<td>9.00</td>
<td>1.00</td>
<td>0.43</td>
<td>1.40</td>
<td>0.05</td>
<td>0.11</td>
<td>0.012</td>
<td>0.055</td>
<td>0.04</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Calcined lime (flux)</td>
<td>0.49</td>
<td>1.95</td>
<td>53.35</td>
<td>0.60</td>
<td>0.06</td>
<td>0.50</td>
<td>0.020</td>
<td>0.04</td>
<td>0.020</td>
<td>41.20</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Coke-breeze (fuel)</td>
<td>2.87</td>
<td>6.66</td>
<td>1.35</td>
<td>3.62</td>
<td>0.11</td>
<td>0.26</td>
<td>0.090</td>
<td>0.04</td>
<td>1.46</td>
<td>0.00</td>
<td>0.00</td>
<td>76.63</td>
<td>6.40</td>
</tr>
</tbody>
</table>

Source: Ajaokuta Steel Complex & National Metallurgical Development Center, JOS

Table 2: Physical and chemical properties of the produced sinter blends

<table>
<thead>
<tr>
<th>S/NO</th>
<th>Agbaja to Itakpe Ratio (%)</th>
<th>% Abrasion</th>
<th>% Shatter</th>
<th>% Tumbler</th>
<th>% Reducibility</th>
<th>% Reduction Decrepitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10:90</td>
<td>4.5</td>
<td>90.0</td>
<td>78.0</td>
<td>73.0</td>
<td>33.0</td>
</tr>
<tr>
<td>2</td>
<td>15:85</td>
<td>4.9</td>
<td>88.0</td>
<td>77.3</td>
<td>72.0</td>
<td>32.5</td>
</tr>
<tr>
<td>3</td>
<td>20:80</td>
<td>5.0</td>
<td>87.0</td>
<td>74.4</td>
<td>68.0</td>
<td>35.2</td>
</tr>
<tr>
<td>4</td>
<td>25:75</td>
<td>5.2</td>
<td>79.8</td>
<td>74.2</td>
<td>67.0</td>
<td>36.2</td>
</tr>
<tr>
<td>5</td>
<td>30:70</td>
<td>5.6</td>
<td>70.6</td>
<td>70.8</td>
<td>65.0</td>
<td>38.0</td>
</tr>
<tr>
<td>6</td>
<td>35:65</td>
<td>6.0</td>
<td>65.5</td>
<td>68.6</td>
<td>60.0</td>
<td>38.3</td>
</tr>
<tr>
<td>7</td>
<td>40:60</td>
<td>6.6</td>
<td>63.8</td>
<td>68.7</td>
<td>58.0</td>
<td>39.6</td>
</tr>
<tr>
<td>8</td>
<td>50:50</td>
<td>7.4</td>
<td>50.6</td>
<td>65.6</td>
<td>56.0</td>
<td>40.9</td>
</tr>
<tr>
<td>9</td>
<td>60:40</td>
<td>9.5</td>
<td>56.6</td>
<td>64.0</td>
<td>55.5</td>
<td>42.0</td>
</tr>
<tr>
<td>10</td>
<td>70:30</td>
<td>10.5</td>
<td>51.3</td>
<td>62.5</td>
<td>54.0</td>
<td>43.6</td>
</tr>
</tbody>
</table>

Blast furnace Specifications: 90 – 93.5% Fe, 78 – 82% P, 69 – 73% CaO

Table 3: Composition of the Produced Sinter blends

<table>
<thead>
<tr>
<th>S/No</th>
<th>Blends</th>
<th>% Fe (%)</th>
<th>% Acid gangue (% (SiO₂ + Al₂O₃))</th>
<th>% P (%)</th>
<th>% CaO (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Agbaja 100%</td>
<td>58.02</td>
<td>20.49</td>
<td>0.65</td>
<td>1.21</td>
</tr>
<tr>
<td>2</td>
<td>Itakpe 100%</td>
<td>66.28</td>
<td>6.57</td>
<td>0.03</td>
<td>8.75</td>
</tr>
<tr>
<td>3</td>
<td>10:90</td>
<td>65.45</td>
<td>7.89</td>
<td>0.09</td>
<td>8.22</td>
</tr>
<tr>
<td>4</td>
<td>15:85</td>
<td>65.04</td>
<td>8.59</td>
<td>0.12</td>
<td>8.02</td>
</tr>
<tr>
<td>5</td>
<td>20:80</td>
<td>64.61</td>
<td>9.30</td>
<td>0.15</td>
<td>7.44</td>
</tr>
<tr>
<td>6</td>
<td>25:75</td>
<td>64.21</td>
<td>9.99</td>
<td>0.18</td>
<td>7.05</td>
</tr>
<tr>
<td>7</td>
<td>30:70</td>
<td>63.80</td>
<td>10.70</td>
<td>0.21</td>
<td>6.88</td>
</tr>
<tr>
<td>8</td>
<td>35:65</td>
<td>63.39</td>
<td>11.39</td>
<td>0.24</td>
<td>6.27</td>
</tr>
<tr>
<td>9</td>
<td>40:60</td>
<td>62.97</td>
<td>12.10</td>
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<td>5.88</td>
</tr>
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<td>50:50</td>
<td>62.15</td>
<td>13.50</td>
<td>0.34</td>
<td>5.10</td>
</tr>
<tr>
<td>11</td>
<td>60:40</td>
<td>61.32</td>
<td>14.92</td>
<td>0.40</td>
<td>4.22</td>
</tr>
<tr>
<td>12</td>
<td>70:30</td>
<td>60.50</td>
<td>14.92</td>
<td>0.41</td>
<td>3.47</td>
</tr>
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</table>

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