Pre-beneficiation of Low Grade Diasporic Bauxite Ore by Reduction Roasting

K. Yılmaz, B. Birol, M. N. Sardede, E. Yiğit

Abstract—A bauxite ore can be utilized in Bayer Process, if the mass ratio of Al₂O₃ to SiO₂ is greater than 10. Otherwise, its Fe₂O₃ and SiO₂ content should be removed. On the other hand, removal of TiO₂ from the bauxite ore would be beneficial because of both lowering the red mud residue and obtaining a valuable raw material containing TiO₂ mineral. In this study, the low grade diasporic bauxite ore of Yalvaç, Isparta, Turkey was roasted under reducing atmosphere and subjected to magnetic separation. According to the experimental results, 800°C for reduction temperature and 20000 Gauss of magnetic intensity were found to be the optimum parameters for removal of iron oxide and rutile from the non-magnetic ore. On the other hand, 600°C and 5000 Gauss were determined to be the optimum parameters for removal of silica from the non-magnetic ore.

Keywords—Low grade diasporic bauxite, magnetic separation, reduction roasting, separation index.

I. INTRODUCTION

A bauxite ore, if the mass ratio of Al₂O₃ to SiO₂ is greater than 10, it can be considered as high-grade bauxite, which can be processed directly by the Bayer process. On the other hand, if this ratio is lower than 8, it is regarded as low-grade bauxite and a pretreatment process should be used before Bayer Process. Although the low grade diasporic bauxite ore of Yalvaç, Isparta in Turkey is a potential raw material for Bayer Process. Its high Fe₂O₃ and SiO₂ content flaws its usability. Additionally Fe₂O₃ content should be max. 2-2.5% if this ratio is lower than 8, it is regarded as low-grade bauxite present in the feed [2].

Fe₂O₃ transforming into a product containing less than 1.6% Fe₂O₃ with a recovery of more than 95% of the iron-free bauxite present in the feed [2].

Rutile (TiO₂), which is a valuable mineral, is also present in the bauxite ores. The separation of rutile also lowers the red mud (Bayer process tailing) amount [7].

There are an amount of studies that involve the removal of iron oxides by magnetizing the iron bearing compounds by reduction roasting. Fe₂O₃ transforming into a product containing less than 1.6% Fe₂O₃ with a recovery of more than 95% of the iron-free bauxite present in the feed [2].

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II. EXPERIMENTAL

A. Materials

In order to research the reduction roasting of bauxite ores, a low grade diasporic bauxite ore and coke was used as raw materials. The chemical composition of the raw materials is given in Table I.

<table>
<thead>
<tr>
<th>Raw materials</th>
<th>Constituent (wt.%)</th>
<th></th>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FeO</td>
<td>SiO2</td>
<td>Al2O3</td>
<td>TiO2</td>
<td>C</td>
</tr>
<tr>
<td>Bauxite</td>
<td>31.53</td>
<td>6.68</td>
<td>43.6</td>
<td>5.56</td>
<td>-</td>
</tr>
<tr>
<td>Coke</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>79.5</td>
</tr>
<tr>
<td>Coke Ash</td>
<td>3.85</td>
<td>47.0</td>
<td>31.5</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

B. Equipment

For comminution of raw materials, laboratory scale crushers, jaw and cone crushers, and ball mill was used and then sieving was performed for classification. The reduction roasting experiments were conducted in a muffle furnace. Wet magnetic separators were used for magnetic separation. The raw materials and products were characterized by ICP-OES analysis.

C. Experimental Procedure

After the raw materials were crushed and ground under 100 mesh they were dried in a drying oven at 105°C for 2 h. Then, ore and coke were mixed with a coal:ore ratio of 1:100. Following experimental procedure was implied in two stages: Reduction and Magnetic separation.

In the reduction stage, to determine the optimum reduction temperature, samples were reduced at 400, 600, and 800°C for 30 min. In magnetic separation step, the reduced samples were subjected to magnetic separation conducted by magnetic separators with low magnetic intensity (5000 Gauss) and high magnetic intensity (20000 Gauss), respectively. Moreover to investigate the effect of particle size on iron oxide removal, samples under 200 mesh were reduced and separated by a magnetic separator with an intensity of 4000 Gauss.

Products obtained from each process were characterized by ICP-OES analysis.

III. RESULTS AND DISCUSSION

The reduction roasting experiments were conducted by reducing the samples at 400, 600, and 800°C for 30 min and the results were compared with the raw ore as given in Fig. 1.

As shown in Fig. 1, Fe and TiO2 contents of the bauxite slightly increase with the increasing reduction temperature. This leads to a consumption of increasing removal of oxygen with the increasing temperature.

The samples, under the particle size of 100 mesh, were then subjected to magnetic separation at 5000 and 20000 Gauss field intensity. The products were analyzed and their separation indexes (SI) were calculated by:

\[ SI = C \times MP/100 \]

where C is the amount of the mineral (wt%) and MP is the mineral proportion (wt%) in the concentrate or tailings.

A. Effect of Reduction Temperature and Magnetic Field Intensity on the FeO Distribution

Table II presents the amount, mineral ratio and separation indexes of FeO after magnetic separation at 5000 and 20000 Gauss for samples reduced at 400, 600, and 800°C, respectively. Moreover the comparison of the separation indexes of FeO versus reduction temperature is given in Fig. 2.

<table>
<thead>
<tr>
<th>Reduction Temp. (°C)</th>
<th>Field Intensity (Gauss)</th>
<th>Amount of FeO (wt%)</th>
<th>Ratio of FeO (wt%)</th>
<th>Separation Index of FeO (wt%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>M</td>
<td>NM</td>
<td>M</td>
</tr>
<tr>
<td>400</td>
<td>5000</td>
<td>40.63</td>
<td>30.38</td>
<td>21.9</td>
</tr>
<tr>
<td>600</td>
<td>5000</td>
<td>46.07</td>
<td>32.81</td>
<td>16.9</td>
</tr>
<tr>
<td>800</td>
<td>5000</td>
<td>40.22</td>
<td>33.42</td>
<td>32.8</td>
</tr>
<tr>
<td>400</td>
<td>20000</td>
<td>38.36</td>
<td>28.4</td>
<td>44.3</td>
</tr>
<tr>
<td>600</td>
<td>20000</td>
<td>41.72</td>
<td>30.96</td>
<td>39.3</td>
</tr>
<tr>
<td>800</td>
<td>20000</td>
<td>39.60</td>
<td>31.84</td>
<td>47.5</td>
</tr>
</tbody>
</table>

M and NM represent the magnetic and non-magnetic fractions of the sample, respectively.

Fig. 2 Separation index changes of FeO, for magnetic and non-magnetic fractions of samples with the reduction temperature

As given in Table II and Fig. 2, increasing temperature increases the separation index of FeO in magnetic fractions, but it decreases after 600°C in non-magnetic fraction. Besides, when high magnetic intensity is used he iron oxide amount in the magnetic fracture of the sample increases. Therefore it is possible to mention that, increasing temperature increases the magnetite formation and higher intensity values can collect the
iron oxide into the magnetic fracture. So, optimum values to collect iron oxide to magnetic fracture are 800°C for reduction temperature and under magnetic intensity of 20000 Gauss. Also 600°C and 5000 Gauss is proper for collecting iron oxide in non-magnetic fracture.

B. Effect of Reduction Temperature and Magnetic Field Intensity on the TiO2 Distribution

The amount, mineral ratio and separation indexes of TiO2 after the experiments and separation indexes of TiO2 are given in Table III and Fig. 3, respectively.

<table>
<thead>
<tr>
<th>Reduction Temp. (°C)</th>
<th>Field Intensity (Gauss)</th>
<th>Amount of TiO2 (wt%)</th>
<th>Ratio of TiO2 (wt%)</th>
<th>Separation Index of TiO2 (wt%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>NM</td>
<td>M</td>
<td>NM</td>
</tr>
<tr>
<td>400</td>
<td>5000</td>
<td>5.98</td>
<td>5.16</td>
<td>19.6</td>
</tr>
<tr>
<td>600</td>
<td>5000</td>
<td>5.95</td>
<td>5.62</td>
<td>13.2</td>
</tr>
<tr>
<td>800</td>
<td>5000</td>
<td>6.04</td>
<td>5.80</td>
<td>29.0</td>
</tr>
<tr>
<td>400</td>
<td>20000</td>
<td>5.70</td>
<td>5.21</td>
<td>39.2</td>
</tr>
<tr>
<td>600</td>
<td>20000</td>
<td>5.84</td>
<td>5.63</td>
<td>33.2</td>
</tr>
<tr>
<td>800</td>
<td>20000</td>
<td>5.98</td>
<td>5.72</td>
<td>43.0</td>
</tr>
</tbody>
</table>

M and NM represent the magnetic and non-magnetic fractions of the sample, respectively.

Both Table III and Fig. 3 exhibit that, TiO2 shows a similar behavior with FeOx and ideal parameters for FeOx is also valid for TiO2. This phenomenon can be explained by leucoxene (xFe2O3.yTiO2), formation as previously Cui et.al. (2002) indicated. Reduction roasting of ore reduces the iron oxide part by making leucoxene more magnetic and therefore easier to separate from rutile using magnetic separation [6].

C. Effect of Reduction Temperature and Magnetic Field Intensity on the Al2O3 and SiO2 Distribution

Al2O3 and SiO2 fraction in both magnetic and non-magnetic fractions are given in Table IV, Fig. 4 and Table V and Fig. 5, respectively.

Both SiO2 and Al2O3 were mostly collected in the non-magnetic fracture, due to their non-magnetic structure. Although with increasing temperature separation index in non-magnetic fracture decreases, this phenomenon may occur due to the inadequate mineral liberalization. Therefore, comminution to lower particle sizes should be investigated.

800°C for reduction temperature and 20000 Gauss magnetic intensity are the optimum parameters for removal of iron oxide and rutile from the non-magnetic ore. However, when these parameters are applied, more SiO2 resides in non-magnetic fracture and more Al2O3 is spared to the magnetic fracture.
IV. CONCLUSIONS

To be able to use a low grade bauxite ore in Bayer Process, its high FeO and SiO2 content should be removed. Additionally if the TiO2 content of the ore can be removed, it would be beneficial because of both lowering the red mud residue and obtaining a valuable raw material containing TiO2 mineral.

In this study, the low grade diasporic bauxite ore was roasted under reducing conditions, in order to obtain more suitable form of iron oxide and rutile for magnetic separation. According to the experimental outputs the following results were concluded;

- Increasing temperature increases the magnetic properties of almost all the minerals investigated.
- Higher magnetic intensity in magnetic separation, increases the mineral proportion in the magnetic fracture.
- 800°C for reduction temperature and 20000 Gauss magnetic intensity were found to be the optimum parameters for removal of iron oxide and rutile from the non-magnetic ore.
- 600°C for reduction temperature and 5000 Gauss magnetic intensity were determined to be the optimum parameters for removal of silica from the non-magnetic ore.
- After this pre-investigation, further researches should be performed in order to determine more effective conditions of reduction roasting and detect the phases in magnetic and non-magnetic fractions.

REFERENCES