Effect of Magnetite-Containing Bauxite Residue on High-Pressure Alkaline Leaching of Boehmitic Bauxite and Subsequent Thickening Rate

Malal Mamadou Diallo[1], Andrei Shoppert[2], Irina Loginova[3] and Dmitry Valeev[4]
1. Master student
2. Professor (assistant)
3. Professor
Department of nonferrous metals metallurgy – Ural Federal University, Yekaterinburg, Russia
4. Researcher
Laboratory of Sorption Methods – Vernadsky Institute of Geochemistry and Analytical Chemistry of the Russian Academy of Sciences, Moscow, Russia
Corresponding author: a.a.shoppert@urfu.ru
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Abstract

This study investigates the potential of using magnetite-containing bauxite residues as an aid in the high-pressure alkaline leaching of boehmitic bauxite for alumina production. The addition of reduced bauxite residue significantly influenced the leaching process and the chemical composition of the solid residue. Furthermore, addition of this residue improved the thickening rate of the slurry by a factor of 1.5 and reduced Na_2O losses by 20 % without the need of lime. The addition of lime and reduced BR improved the thickening rate of the slurry by a factor of 1.8 and reduced Na_2O losses by 30 % An analysis of the solid residues, including zeta-potential measurements, revealed a change in surface potential that contributes to accelerated thickening. The suggested approach offers a promising solution for waste utilization in the alumina extraction process.

Keywords: Red mud, magnetite, Al-goethite, conversion.

1. Introduction

In the treatment of bauxite to produce alumina by the Bayer process, the feedstock is subjected to high-pressure leaching with a recycled alkaline-aluminate solution to produce a saturated solution and a solid leach residue – bauxite residue (BR). The BR consists mainly of unreacted iron and titanium minerals as well as solution desilication products (DSP, $Na_6[Al_6Si_6O_{24}]$ Na_2O).

As a result, the BR consists of approximately 50% iron oxide, with the remainder being DSP (Disodium Silicoaluminate Phase) and other impurities. The yield of BR can be up to 100 % of weight of the raw bauxite, especially when the addition of CaO is high. The addition of CaO is necessary to reduce losses of alkali due to the formation of hydrogarnet ($Ca_3Al_2Si_3(OH)_{12}$). It also increases the sedimentation properties of the BR, making it easier to separate solid particles from the aluminate solution.

Li et al. [1–3] shown that in the leaching of bauxite with the addition of iron, aluminium or organic powders to establish reduction conditions, there is no need to use calcium oxide. In addition, the extraction of Al in solution is increased and the yield of BR is decreased. The process is based on the conversion of hematite in bauxite to magnetite by reaction (1). This reaction occurs in the presence of Fe^{2+} ions in solution [4–6].

$$Fe_2O_3(s) + Fe(OH)_3^-(aq) = Fe_3O_4(s) + H_2O(l) + OH^-(aq) \quad (1)$$

Previous study [7, 8] shown that reductive leaching can be performed at atmospheric pressure by adding $FeSO_4$. This produces a red mud that is rich in iron with magnetite as the main mineral. The solid residue was found to be easier to separate from the aluminate solution and to thicken faster. This is due to the finalization of the processes for the extraction of aluminium from the aluminogoethite (Al-goethite) and the aluminohematite (Al-hematite).

In this research, an attempt was made to use reduced BR (RBR) for high-pressure Bayer leaching (HPBL) of boehmitic bauxite without adding CaO for alumina extraction simultaneously with Al-goethite and Al-hematite dissolution, as well as to increase the rate of thickening of the BR particles.

2. Materials and Methods

2.1 Materials and Reagents

Boehmitic bauxite was collected from Ural alumina refinery (Sverdlovsk region, Russia). Reduced bauxite residue was obtained by the method described elsewhere [9] from the Friguia alumina refinery (Guinea) bauxite residue, which utilizes gibbsite bauxite for alumina production by the Bayer method. The chemical composition of the bauxite and BR is given in Table 1. XRD of boehmitic bauxite and BR is shown in Figure 1.

Table 1. Chemical composition of the raw boehmitic bauxite and reduced bauxite residue (RBR), wt. %.

Sample	Fe_2O_3	Al_2O_3	SiO_2	TiO_2	Na_2O	CaO	MgO	SO_3	P_2O_5	Other	LOI[1]
Bauxite	25.5	51.7	6.4	2.7	0.1	0.5	0.4	0.02	0.3	1.1	11.3
RBR	74.1	4.7	5.9	5.7	3.9	0.7	0.1	0.2	0.1	1.2	3.4

[1] *Lost on ignition at 1100 °C.*

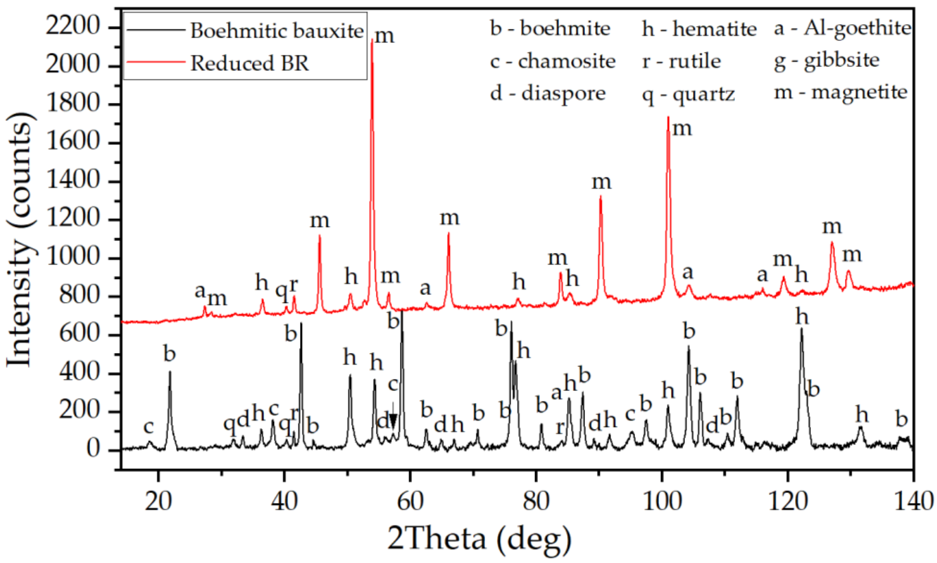

Figure 1. XRD patterns of the raw bauxite and reduced bauxite residue (RBR).

The raw bauxite contained boehmite (AlOOH), hematite (Fe2O3), rutile (TiO_2), quartz (SiO_2), and chamosite ((Fe^{2+}, Mg, Al, $Fe^{3+})_6$(Si, $Al)_4O_{10}$(OH, O)). The RBR consisted of magnetite, hematite, and a desilication product. The presence of Al-goethite and Al-hematite in the bauxite was confirmed by Mössbauer spectroscopy [8]. Analytical-grade sodium hydroxide (NaOH) for solution preparation was purchased from JSC Soda (Sterlitamak, Russia). The mother liquor for HPBL was obtained from the Ural Alumina Refinery and contained 280.6 g/L caustic alkali

According to the XRD diagram in Figure 5, the main phases of iron in the solid residue of leaching with RBR are hematite and magnetite in proportions of about 60 % and 40 % respectively. The presence of magnetite allows the extraction of a magnetic fraction from this residue by magnetic separation [10–12].

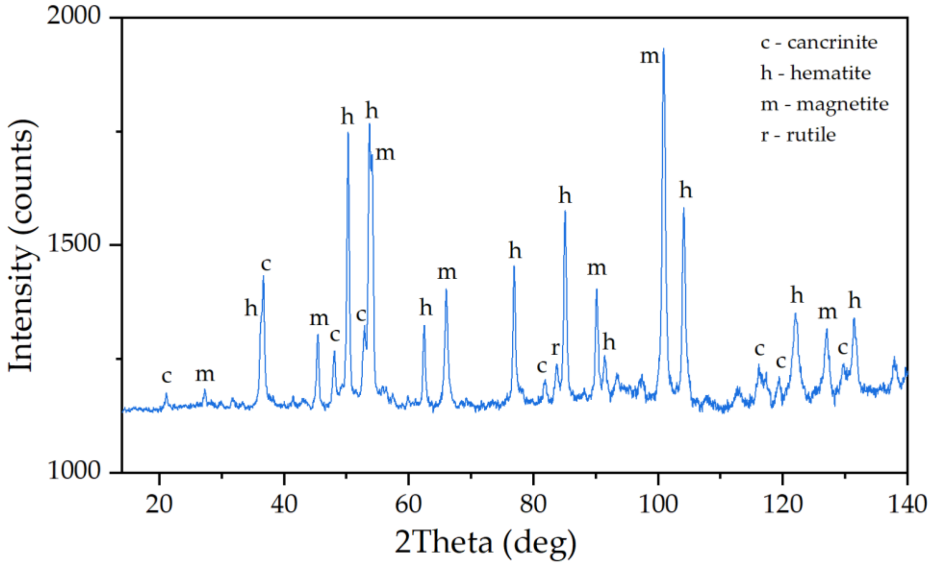

Figure 5. XRD pattern of the solid residue after bauxite leaching with the addition of the reduced BR.

4. Conclusions

The effect of reduced BR addition on high-pressure alkaline leaching of boehmitic bauxite and following thickening rate was investigated in this study. The main conclusions are as follows: After high-pressure leaching with the addition of 9 % reduced BR, the thickening rate increases by 1.5 times. Leaching of boehmitic bauxite with addition of lime and reduced BR in the amount of 9 % of bauxite mass increases the thickening rate up to 1.8 times. This phenomenon can be explained by the zeta-potential differences observed in this study. The repulsive forces are stronger between ordinary BR particles than between BR particles after the addition of reduced BR. Additionally, the zeta-potential of RBR can become positive due to its large specific surface area and the consumption of OH^- during the addition of FeSO4. As a result, due to weaker repulsive forces, a higher thickening rate is observed when reduced BR is added.

Leaching of boehmitic bauxite with addition of lime and reduced BR in the amount of 9 % of bauxite mass, Na_2O losses are reduced by 30 %. The Fe_2O_3 content in the solid residue of boehmitic bauxite leached with the addition of reduced BR reaches 50–52% against 46% in conventional leaching according to the Bayer process.

5. Funding

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