

Reductive Roasting Process for the Recovery of Iron Oxides from Bauxite Residue through Rotary Kiln Furnace and Magnetic Separation

Chiara Cardenia¹, Buhle Xakalashé², Efthymios Balomenos³, Dimitrios Panias⁴ and Bernd Friedrich⁵

1. PhD Candidate

3. Senior Researcher,

4. Professor,

National Technical University of Athens, School of Mining and Metallurgical Engineering, Athens, Greece

3. External Associate Residue Valorisation, Aluminium of Greece, St Nicolas Plant, Viotia, Greece

Corresponding author: cardeniach@metal.ntua.gr

2. PhD Candidate,

5. Professor,

RWTH Aachen, IME, Process Metallurgy and Metal Recycling, Aachen, Germany

Abstract

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Bauxite residue (BR), the main by-product formed during the Bayer process for alumina production, is a secondary raw material source, containing usually iron (Fe), titanium (Ti), aluminium (Al) and in some cases rare earth elements (REEs) including Sc. This work addresses the high temperature carbothermic conversion of hematite and goethite in the BR to magnetic iron phases. The reductive process developed in a laboratory scale static tube furnace, was scaled up using a rotary kiln furnace. Experiments were carried out by mixing BR with a carbon source ($C/BR=0.225$) and an additive ($Na_2CO_3/BR=0.25$), at 1000 °C in the presence of N_2 . The results show that hematite is almost fully (> 99 wt.%) converted to magnetic iron phases after 1 hour. Subsequently, this work was focused on the magnetic separation process through a wet high-intensity magnetic separator. Two current intensities (0.01 and 0.5 A) were employed to collect three fractions (Magnetic I, Magnetic II and Non Magnetic), 70 % of the total Fe content was concentrated in the first magnetic fraction, producing a secondary iron concentrate while the non-magnetic fraction is enriched in Ti and REEs.

Keywords: Rotary kiln, iron recovery, magnetic separation, bauxite residue.

1. Introduction

Bauxite residue (BR), also known as red mud, is the major by-product of the alumina industry. During the production of alumina from bauxite ores, about 0.9 to 1.5 tonnes of BR are generated per tonne of alumina produced, through the Bayer process [1] and this value exceeds 150 million tonnes per year worldwide [2]. Since bauxite residue contains valuable substances including iron (Fe), titanium (Ti), aluminium (Al) and rare earth elements (REEs), it can be considered as a secondary raw material [3 - 4]. For this reason, the utilization of this waste has been explored in the last decades aiming to reach zero-waste valorisation [5]. Fe is generally present in BR in a range of 14 – 45 wt.% depending on the initial bauxite ore used [4].

Karst bauxites are usually high in iron, so various techniques have been investigated for iron recovery from the respective BR [6]. In this framework, the following research has been developed with the purpose of quantitatively converting hematite and goethite in the BR to magnetic iron phases by a carbothermic reductive roasting process carried out through a rotary kiln furnace and a subsequent magnetic separation. This process will foster the production of an

iron rich concentrate and a non-magnetic residue enriched in Ti and REEs.

2. Experimental

Bauxite residue, provided by Aluminium of Greece S.A., was homogenised, grinded and sieved obtaining a sample with a $D_{50} = 1.87 \mu\text{m}$ (MastersizerTM Particle Size Analyzer). To understand the composition and the distribution of iron phases in BR, physical and chemical characterisation were carried out.

X-ray diffraction analysis (XRD) was conducted using a Bruker D8 Focus analyser. The differential thermal analysis (DTA) was performed using a SETARAM TG Labys-DS-C system in the temperature range of 25 – 1000 °C with a 10 °C/min-heating rate, in air atmosphere. To examine the chemical distribution and composition of the samples microstructure, scanning electron microscopy Jeol 6380LV (SEM) combined with an Oxford INCA Energy Dispersive Spectrometer (EDS) were used. Chemical analyses were executed via fusion method (1000 °C for 1 hour with a mixture of $\text{Li}_2\text{B}_4\text{O}_7/\text{KNO}_3$ followed by direct dissolution in 6.5 % HNO_3 solution) through Inductively Coupled Plasma Mass Spectrometry (ICP-MS), Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) and Atomic Absorption Spectroscopy (AAS).

BR was mixed with lignite coke as the reductant ($C_{\text{fix}} = 87.5 \%$ and ash = 9.0 %) and Na_2CO_3 as the flux following the optimised ratio developed in a laboratory scale static tube furnace (1 g BR: 0.250 g Na_2CO_3 : 0.225 g C). The mixed samples were converted into pellets by using water as binder with a pellet size between 6.35 mm and 12.7 mm, then dried at 105 °C for 24 hours. The roasting process was conducted at 1000 °C in the presence of N_2 for 4 hours, employing a rotary kiln furnace. The batch masses per experiment were fixed to 1.5 kg pellets, and samples were taken at the following intervals: 1 hour, 2 hours, 3 hours and 4 hours.

The collected cinder was milled ($< 90 \mu\text{m}$) and then leached with water (H_2O) at 80 °C for 4 hours with 1.5 % pulp density. Thereafter, the leaching residues were directly processed with a wet high intensity magnetic separator (CarpoTM). To improve the separation between the magnetic portion of the sample and the gangue, two current intensities were applied: 0.01 A at the first pass and 0.5 A at the second pass. Three fractions were collected (Magnetic I, Magnetic II and Non Magnetic) and characterised by XRD, SEM – EDS and chemical analysis.

The process flow diagram for the entire process is presented in Figure 1.

for 4 hours allowing the dissolution of sodium aluminum-silicate phase and the liberation of Fe phases.

The leached products was passed through a wet high intensity magnetic separator, providing a high magnetic fraction that contains the 70 % of the total content of Fe and a non-magnetic residue that is enriched in Ti and REEs content. The magnetic separation process is still under development to increase the purity of the Magnetic I fraction.

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