A New Calcification Transformation Method for Clean Production of Alumina

Tingan Zhang[1], Guozhi Lv[2], Xin He[3], Qingdong Li[4], Bingshen Liu[5], XiaoLei Zhang[6] and Zhuangzhuang Yun[7]
1, 2. Professors
3, 4, 5, 6, 7. PhD students
Northeastern University - School of Metallurgy, Shenyang, China
Corresponding author: lvgz@smm.neu.edu.cn
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Abstract

This paper proposes a novel approach to the clean production of alumina through the source blocking of mineral phase reconstruction, addressing the global challenge of utilizing medium and low-grade bauxite. Based on the characteristics of these bauxite types, we have developed a series of technologies, including "calcification-carbonation", "calcification-biomass," and "calcification-potassium alkali" along with their intersections, to facilitate the clean production of alumina during the dissolution process. This approach enables the efficient recovery of alumina during bauxite leaching while reducing sodium oxide emissions, achieving a Na_2O content of less than 1% in the final transformed slag. This lays a theoretical foundation for the scalable and harmless utilization of red mud. The elimination of red mud varies with different transformation processes in various regions. The calcification-carbonation method not only efficiently recovers alumina but also allows the new red mud to be utilized in cementation or soil applications. The calcification-biomass method achieves a hematite to magnetite transformation rate exceeding 90 %, enabling the recovery of iron oxide in low magnetic field strengths. The calcification-potassium alkali method, as a new dissolution system, exhibits a higher alumina dissolution rate than the Bayer process, and the resulting transformation slag can be repurposed as a mineral compound fertilizer, achieving high-value utilization. Through case studies, we systematically elaborate on the fundamental concepts, principles, and methodologies of the "Calcification Transformation" series, elucidating the evolution of the mineral phase and briefly introducing the engineering processes involved. This work successfully achieves the goal of source blocking and demonstrates significant theoretical and practical implications for advancing scientific and technological progress in the alumina industry.

Keywords: Alumina clean production, Medium and low-grade bauxite, Calcic carbonization, Calcic biomassification, Calcic potash alkali

1. Introduction

Driven by the rapid development of the global economy, alumina has emerged as a crucial raw material, with its consumption continually rising across various sectors, particularly in the production of aluminium products. However, the increasing scarcity of high-quality bauxite presents significant challenges. The effective utilization of low- and medium-grade bauxite, along with the environmental pollution caused by red mud generated during alumina production, has become a critical issue for the sustainable development of the industry.

Currently, over 95 % of global alumina production utilizes the Bayer process, which, while dominant, has significant shortcomings [1]. Firstly, the Bayer method imposes stringent requirements on the aluminium to silicon ratio of bauxite (Al/Si > 7), making it challenging to efficiently and economically process low-grade bauxite resources. This challenge is exacerbated by the increasingly depleted state of global bauxite resources [2]. For instance, in China, bauxite reserves account for only 3 % of the world's total, with most being low-grade ores; high-silica bauxite ores constitute over 90 % [3]. Consequently, resource utilization faces substantial challenges. Secondly, the Bayer production process generates 1.0 to 1.5 tonnes of red mud for every tonne of alumina produced. The global reserves of red mud exceed 4 billion tonnes, with an annual increment of 120 million tonnes [4]. In China, the annual discharge of Bayer's red mud exceeds 100 million tonnes, accounting for more than half of the global emissions [4]. Red mud is characterized by its strong alkalinity and the presence of harmful substances, with a utilization rate of only 7.6 %. The mainstream method of dry storage not only occupies considerable land resources but also poses serious environmental pollution risks [5]. For example, the leaching of heavy metal ions from red mud can contaminate soil and water bodies, while the release of alkaline substances can disrupt ecological balance, threatening the surrounding environment [6, 7].

In light of this, the development of an alumina clean production process that effectively addresses the challenges associated with the utilization of low- and medium-grade bauxite, while simultaneously mitigating red mud pollution at its source, is of paramount importance. This necessity holds significant practical relevance and strategic implications for advancing the green and sustainable development of the alumina industry. Against this backdrop, this paper introduces a novel alumina clean production method based on mineral phase reconstruction, termed the calcification transformation method. This approach emphasizes the mineral phase characteristics of bauxite and red mud, leveraging the principle of mineral phase reconstruction to disrupt the sodium-aluminium-silicon bond present in red mud generated by the traditional Bayer method. By reconstructing the equilibrium solid phase during the dissolution process, the method facilitates the efficient recycling of alumina from middle- and low-grade bauxite while simultaneously reducing sodium oxide emissions. This lays a theoretical foundation for the large-scale, harmless utilization of red mud. The related technologies can be categorized into three sub-methods: the calcification-carbonation method, the calcification biomass method, and the calcification potassium alkali method. This paper will systematically elucidate the principles and methodologies of these calcification transformation methods in treating low-grade bauxite ore and the evolution of the mineral phase. Additionally, it will provide a concise overview of the engineering processes involved, with the aim of offering theoretical support for achieving green, low-carbon, sustainable, and high-quality clean production within the alumina industry.

2. Principles of Calcification Transformation

2.1 Calcification-Carbonization Method

The calcification-carbonation method is a clean production technology for alumina that focuses on the reconstruction of the mineral phase. This method is primarily employed for processing medium- to low-grade bauxite and Bayer red mud. By altering the equilibrium solid phase during the dissolution process of bauxite or red mud, a new structure of alkali- and aluminium-free red mud is produced. This approach facilitates the efficient recovery of alumina while promoting the reduced and harmless utilization of red mud [8, 9].

The primary reactions involved in the two core aspects of the calcification-carbonation method for treating bauxite and red mud – namely, pressurized calcification and pressurized carbonation – are outlined as follows.

Calcification process: During the dissolution phase of the Bayer method, calcium oxide is introduced, facilitating the incorporation of all silicon from bauxite or red mud into the hydrated garnet phase. This results in the formation of a calcified transformation slag devoid of sodium

4. References

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