High-Intensity Magnetic Separation of Bauxite Residue for Iron Recovery

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Abstract

As a highly alkaline solid waste generated during bauxite refining, bauxite residue poses significant challenges to environmental protection and resource utilization due to its massive accumulation. This study systematically investigates a high-intensity magnetic separation process – referred to as "one roughing, one cleaning, and one scavenging stage" – by exploring the effects of different parameters on the recovery efficiency of magnetic minerals through experiments, optimizing the process flow, and analysing the potential value of this technology in resource recycling and environmental protection. The results show that by properly adjusting key parameters such as background magnetic field intensity and slurry concentration, the recovery rate of metallic elements in bauxite residue can exceed 50 %, providing technical support for the high-value utilization of bauxite residue.

Keywords: Bauxite residue, High-intensity magnetic separation, Metal recovery, Resource utilization

1. Introduction

1.1 Research Background and Significance

Bauxite residue, a highly alkaline solid waste generated during bauxite refining, is produced in massive quantities. As the world's leading aluminium producer, China accounts for over 50 % of both global alumina and aluminium output, generating approximately 100 million tonnes of bauxite residue annually. However, the current comprehensive utilization rate of bauxite residue in China is only 12 %, with 1 to 1.5 tonne of residue generated for every tonne of alumina produced. Such large-scale storage needs of bauxite residue not only impact future land-use but also poses severe environmental threats, as its high alkalinity allows chemical components to impact soil and groundwater.

In this context, high-intensity magnetic separation technology becomes particularly important in bauxite residue treatment. Through this method, valuable metals such as iron can be recovered from bauxite residue, enabling resource recycling, reducing dependence on primary mineral resources, and alleviating China's heavy reliance on imported bauxite and iron ore. At the same time, high-intensity magnetic separation can enhance the overall utilization rate of bauxite residue, mitigate environmental and safety risks associated with its storage, and promote the sustainable development of the aluminium industry. It plays a crucial role in advancing ecological civilization and ensuring resource security.

1.2 Research Status at Home and Abroad

Currently, technologies for treating bauxite residue mainly include storage, landfilling, utilization as a construction material, and resource recovery. Traditional storage methods pose

environmental risks, while use as a construction material is limited by fluctuations in residue composition and is generally low value- added. In terms of resource recovery, techniques such as magnetic separation, flotation, and acid leaching have become research hotspots. High-intensity magnetic separation can be widely applied in iron recovery from bauxite residue due to its chemical-free process, high efficiency, and environmental benefits. However, existing high-intensity magnetic separation processes often suffer from low recovery rates and poor concentrate grade. The "one roughing, one cleaning, and one scavenging stage" separation process offers the potential to enhance metal recovery and reduce impurity content through classification and separation, but its parameter optimization and process adaptability require further research.

In the past decade, research on bauxite residue has mainly focused on improving its comprehensive utilization to address the environmental and resource waste problems caused by its large-scale accumulation. Figure 1 shows the comprehensive utilization volume and rate of bauxite residue from 2011 to 2024.

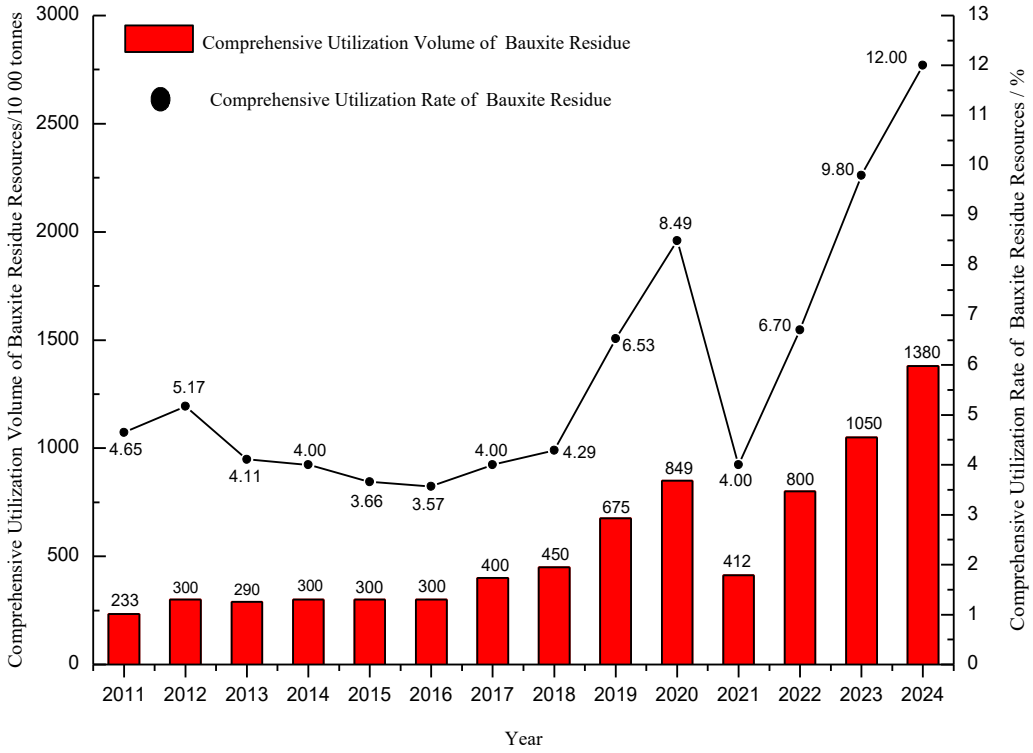

Figure 1. Comprehensive utilization volume and rate of bauxite residue, 2011–2024.

From 2011 to 2024, the comprehensive utilization volume of bauxite residue has shown an overall upward trend, increasing from 2.23 million tonnes in 2011 to 13.8 million tonnes in 2024, with accelerated growth after 2018. From 2022 to 2024, both the increase (5.8 million tonnes) and growth rate (72 %) were significant due to the higher base volume. The utilization rate fluctuated between 2011 and 2024, reaching 8.49 % in 2020, dropping sharply to 4 % in 2021, and then rising again, but staying below 10 % throughout 2023, finally reaching 12 % in 2024.

As shown in the figure, there is no simple linear relationship between utilization volume and utilization rate. From 2011 to 2017, the utilization volume remained relatively stable, with minor fluctuations in the utilization rate; from 2018 to 2020, as utilization volume increased, the utilization rate also rose rapidly; however, in 2021, the volume fell to 4.12 million tonnes, accompanied by a sharp drop in utilization rate; subsequently, from 2022 to 2024, both utilization

(3) The process is economically feasible, with a short payback period and significant environmental benefits, providing an effective technical route for the resource utilization of bauxite residue.

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