Development of Activator Technology for Flotation Desulphurization of High-Sulphur Bauxite

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Abstract

With the rapid advancement of China's alumina industry, the depletion of high-grade bauxite resources has intensified, making the efficient utilization of high-sulphur bauxite a critical challenge for the industry's sustainable development. Traditional flotation desulphurization methods, while effective, rely on strong acid activators such as sulphuric acid and copper sulphate, which pose significant drawbacks including high corrosiveness, environmental pollution, and elevated costs. These limitations are particularly pronounced when processing high-sulphur bauxite with substantial clay content, leading to reduced desulphurization efficiency. Addressing this issue, the development of an environmentally friendly, efficient, and stable desulphurization activator has emerged as a pressing technological imperative. This study introduces an innovative composite activator system based on phytic acid for the desulphurization of high-sulphur bauxite. Through the optimization of its chemical structure and physical properties, the proposed activator significantly enhances desulphurization efficiency while concurrently reducing energy consumption and environmental impact. The research encompasses a comprehensive analysis of the mineralogical characteristics of high-sulphur bauxite, comparative flotation desulphurization experiments using conventional activators, and the development and application of the novel activator in high-sulphur bauxite processing. Experimental results demonstrate that the new activator not only exhibits high selectivity in sulphide removal but also minimizes the dissolution of valuable aluminium minerals, aligning with the principles of green metallurgy. When applied to raw ore with a sulphur content of 5.04 %, the flotation desulphurization process utilizing the composite activator reduced collector consumption by over 20 % compared to traditional methods. Employing a "one roughing, three cleaning, and three scavenging" closed-circuit flotation process, the system achieved a high-quality aluminium concentrate with a yield of 87.9 % and a sulphur content of 0.47 %, alongside a sulphur concentrate with a yield of 12.1 % and a sulphur content of 38.3 %.The novel activator offers a groundbreaking solution for the efficient utilization of high-sulphur bauxite resources, holding significant theoretical and practical value for advancing sustainable practices in bauxite resource development. Its application is expected to contribute substantially to the industry's efforts in resource optimization and environmental stewardship.

Keywords: High-Sulphur Bauxite, Flotation Desulphurization, Activator.

1. Introduction

With the rapid development of China's alumina industry, the demand for high-grade bauxite has steadily increased, leading to a gradual decline in the quality of existing bauxite reserves. Simultaneously, the vast domestic resources of high-sulphur bauxite have not received adequate attention, posing a severe threat to the sustainable development of China's aluminium industry. Addressing the challenges of sulphur removal from low-quality, high-sulphur bauxite and achieving its cost-effective utilization have long been critical issues hindering the high-quality development of the alumina industry.

Flotation desulphurization is currently one of the most advanced methods for bauxite desulphurization. This technique is well-suited for processing high-sulphur bauxite ores, offering excellent desulphurization performance, economic efficiency, and technical feasibility. Traditional activators such as sulphuric acid or copper sulphate have been widely employed. However, sulphuric acid, as a strong acid, exhibits high corrosiveness, environmental hazards, safety risks, and detrimental effects on worker health. Its industrial application is further complicated by challenges in transportation, storage, production management, and pipeline corrosion. Copper sulphate, while effective, is costly and also corrosive, leading to long-term damage to flotation equipment and pipelines, thereby compromising the desulphurization process. Moreover, conventional activators demonstrate poor performance in activating high-sulphur bauxite slurries with high clay content, adversely affecting the quality of the final bauxite concentrate after flotation. Consequently, the development of a novel activator for high-sulphur bauxite flotation under weakly acidic or acid-free conditions is of paramount importance. Such innovation is critical to achieving cleaner production in mineral processing plants, enhancing economic efficiency, and promoting sustainable mining practices [1].

The research and development of new desulphurization activators aim to address the limitations of traditional methods, including low efficiency, high costs, and poor environmental adaptability. By optimizing the chemical structure and physical properties of activators, their activity and selectivity in the desulphurization process can be significantly enhanced, enabling efficient sulphide removal while minimizing damage to valuable mineral components. Furthermore, the application of novel activators can reduce energy consumption and waste emissions, aligning with the principles of green production.

Globally, increasingly stringent environmental regulations and demands for resource efficiency have positioned the development of advanced desulphurization activators as a key industry focus. These innovations not only help enterprises meet environmental standards and enhance market competitiveness but also facilitate the comprehensive utilization of bauxite resources, driving sustainable development across the sector [2].

In summary, the development of novel desulphurization activators represents an effective strategy to address current challenges in bauxite resource exploitation. It serves as an essential pathway toward achieving dual objectives: the efficient utilization of high-sulphur bauxite and environmental protection. With ongoing advancements in scientific research and technological innovation, these next-generation activators are poised to demonstrate even broader application prospects in the field of bauxite resource development.

2. Characterization of Bauxite Ore

2.1 Mineralogical Characterization

The ore samples were selected from high-sulphur bauxite deposits in a specific region of Guizhou Province. Mineralogical analysis of the samples was conducted using X-ray fluorescence (XRF) spectroscopy and QEMSCAN (Quantitative Evaluation of Minerals by Scanning Electron Microscopy). Sulphur content was determined by an infrared carbon-sulphur analyser, while organic carbon was measured via titration. The multi-element analysis results of the ore samples are summarized in Table 1.

(2) For the raw ore containing 5.04 % sulphur, a closed-circuit flotation desulphurization test was conducted using conventional activator copper sulphate ($CuSO_4$). The process adopted the "one roughing, three cleaning, and three scavenging" flotation flowsheet with the following parameters: Grinding fineness: 80.25 % passing 0.074 mm, pH: 9; reagent dosages: depressant: 2000 g/t; Activator: 100 g/t; Collector: 900 g/t; Frother: 1/3 of the collector dosage (300 g/t). The test yielded: Aluminium concentrate: 86.91 % yield, 0.55 % sulphur content; Sulphur concentrate: 13.09 % yield, 34.87 % sulphur content.

(3) Impact of Composite Activator Ratios on Desulphurization Performance Experimental studies on phytic acid-based composite activators with varied Cu^{2+}/NH_4^+ ratios revealed the following trends: Aluminium concentrate sulphur content initially decreased with increasing Cu^{2+} content but subsequently increased, while sulphur concentrate sulphur content gradually rose and stabilized. Optimal performance was achieved at a $Cu^{2+}:NH_4^+$ ratio of 3:6, corresponding to the phytic acid-derived metal complex $[Cu_3(NH_4)_6(C_6H_6O_{24}P_6)]$. This formulation yielded: Aluminium concentrate: 0.37 % sulphur content (lowest observed); Sulphur concentrate: 40.66 % sulphur content (highest grade). These results confirm that $[Cu_3(NH_4)_6(C_6H_6O_{24}P_6)]$ exhibits optimal flotation desulphurization efficacy, balancing sulphur removal efficiency and concentrate quality.

(4) Optimization of Flotation Desulphurization Using Novel Composite Activators: Comparative studies revealed that collector dosage was reduced by over 20 % when replacing the conventional activator copper sulphate ($CuSO_4$) (collector dosage: 900 g/t) with the novel composite activator (collector dosage: 700 g/t). For the raw ore containing 5.04 % sulphur, the closed-circuit test under the "one roughing, three cleaning, and three scavenging" flowsheet achieved: Aluminium concentrate: 87.92 % yield, 0.47 % sulphur content; Sulphur concentrate: 12.08 % yield, 38.34 % sulphur content.

6. Reference

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