Progress on Quality Improvement Technology of Low-Quality Complex Bauxite

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Abstract

As the world's most important source of aluminium metal, bauxite is a strategic mineral resource that supports the development of modern industry. As the world's largest producer and consumer of primary aluminium, China has formed a complete aluminium industrial chain, but restricted by resource endowments, aluminium industry faces structural contradictions: on the one hand, the uneven distribution of domestic bauxite resources, high-quality resources have been nearly exhausted, resulting in a long-term dependence on imported ore above 60 %; on the other hand, low quality complex bauxite resources are relatively rich, but because of the ore "poor, fine, miscellaneous", comprehensive utilization is difficult, resulting in a serious backlog of resources. Aiming at two typical low quality bauxite types, high silicon type and high sulphur type, this study introduced the research status and existing problems of bauxite dressing technology and then proposed the efficient development and utilization methods of low-quality bauxite and clarified the future research direction of dressing technology. At the same time, to promote the sustainable development and utilization of domestic low-grade complex bauxite resources, it is necessary to give full play to the strategic role of the national "Belt and Road" initiative. It is recommended to build a multi-level bauxite resource security system, optimize the import strategy, realize the coordinated development of domestic resource development and international resource supply, and improve the bauxite resource security ability from the source. Provide solid resource support for the sustainable development of aluminium industry.

Keywords: Low quality complex bauxite, Mineral resources, Beneficiation technology, Desulphurization, Desilication.

1. Introduction

Aluminium is the most abundant metallic element in the Earth's crust and the second only to oxygen and silicon, and it is also the second most abundant metallic resource. As a core raw material in the aluminium industry, bauxite is widely used in fields such as alumina smelting, refractory material preparation, and the ceramic industry [1].

As the world's largest producer and consumer of aluminium, China's bauxite mining scale continues to expand. According to the latest statistics, China's bauxite reserves in 2024 are approximately 680 million tonnes, accounting for only 2 % of the global total reserves. Meanwhile, the output during the same period is as high as 93 million tonnes, making up 21 % of the global total output and ranking third in the world (only after Guinea and Australia). The supply and demand situation are becoming increasingly severe. Compared with the rest of the world, China's bauxite resource endowment is complex. Over 98 % of the proven deposits belong to the ancient weathering crust sedimentary type of boehmite ore, with typical characteristics of high aluminium, high silicon, low iron and accompanied by impurities such as sulphur and carbon.

Due to the fine particle size distribution, complex mineral composition and high impurity content of such ores, traditional beneficiation processes are confronted with problems such as lengthy procedures, high energy consumption and difficult tailings disposal, further increasing the cost of alumina smelting. To address this issue, China, on the one hand, selects imported high-quality bauxite, and on the other hand, intensifies the impurity removal and purification of the abundant reserves of low-grade and complex bauxite to meet the raw material requirements for bauxite products [2–5]. Therefore, conducting a comprehensive analysis of the current resource status of bauxite in China, the progress of beneficiation and quality improvement technologies for low-grade and complex bauxite, and the existing problems, and highlighting the future research directions, is of great significance for promoting the development and utilization of bauxite in China and enhancing the resource guarantee capacity.

2. Nature of Bauxite Resources in China

The bauxite resources in China are mainly sedimentary boehmite monohydrate, featuring significant regional distribution concentration and special ore quality. The aluminium-silicon ratio of this type of ore is generally low, and the contents of impurities such as sulphur, iron and silicon are relatively high, resulting in high processing difficulty and energy consumption. These complex mineral characteristics pose significant challenges for bauxite in China in terms of beneficiation quality improvement and alumina production.

(1) The basic reserves of bauxite in China are relatively low. The proportion of low-grade bauxite exceeds 90 %, and high-grade bauxite is scarce, and most of them are of the boehmite type with high energy consumption for dissolution. Compared with the laterite bauxite deposits abroad, the sedimentary deposits in China have thin bodies and deep burial, and the reserves suitable for open-pit mining only account for 34 %. The ratio of aluminium to silicon in the ore is generally lower than the international average level. Shanxi, Guangxi, Guizhou and Henan provinces and autonomous regions concentrate over 90 % of the country's resources [6].

(2) There are mainly two types of boehmite deposits: sedimentary and accumulative [7]. Sedimentary bauxite accounts for 82 % of the total reserves in the country and is mainly distributed in the sedimentary environment of ancient weathering crust. In the ore, hydrated bauxite closely coexists with siliceous minerals such as kaolinite and illite. The accumulation type deposits are represented by Pingguo, Guangxi, which are characterized by large ore body thickness and high aluminium-silicon ratio, but the reserves only account for 18 %.

(3) The aluminium-silicon ratio of bauxite is generally low, and the content of impurities such as sulphur, iron and silicon is high [8]. The boehmite in the ore is closely interwoven with silicate minerals, and the energy consumption for dissolution is high. Therefore, it is necessary to carry out mineral processing for quality improvement (such as silicon removal by flotation and iron removal by magnetic separation) to achieve resource utilization. The reserves of high-sulphur bauxite (with sulphur content exceeding 0.8 %) amount to hundreds of millions of tonnes. The presence of sulphur in the ore can easily corrode equipment and reduce the purity of alumina. It needs to be sulphurised to meet the production requirements of the Bayer process.

(4) It generally shows the symbiotic characteristics of multiple elements. In the occurrence system, in addition to the main ore body, there are often abundant associated resources. In typical bauxite deposits, refractory clay, carbonate rocks and iron ore can be seen coexisting with bauxite. The associated components mainly include useful elements such as gallium, vanadium, lithium, titanium and scandium [9].

With the continuous increase in China's alumina production capacity, the consumption of bauxite raw materials has been significantly pushed up. However, limited by the endowment of bauxite with efficient desilication performance and cooperate with physical sorting chains in order to achieve industrial implementation under the "dual carbon" goal.

(2) In terms of desulphurization of high sulphur bauxite, although roasting desulphurization can effectively remove sulphur, there is a problem of high energy consumption, and the stability of desulphurization effect is insufficient during large-scale industrial production. It is necessary to develop efficient roasting equipment and optimize process parameters to reduce energy consumption and costs; As the most widely used desulphurization method currently, flotation desulphurization has become increasingly complex as the grade of bauxite decreases and the sulphur content increases. Therefore, it is necessary to develop flotation reagents with stronger selectivity and optimize the flotation process; chemical oxidation desulphurization technology has a certain effect on the transformation of sulphur forms, but further research is still needed on the oxidation reaction mechanism of sulphur forms other than S^{2-} in sodium aluminate solution; microbial desulphurization, as an environmentally friendly technology, can improve desulphurization efficiency by screening more adaptable and efficient bacterial strains, optimizing bacterial culture conditions.

(3) The selection of bauxite desilication and desulphurization technologies and their cost impacts should be dynamically evaluated based on ore characteristics, process compatibility, and logistics conditions. At the ore property level, the form and content of silicon and sulphur directly determine the technical route; process selection needs to balance initial investment, operating costs, and by-product benefits; fluctuations in ocean freight rates have strengthened the strategic value of local processing. Compared with imported ores, the economic efficiency of domestic high-sulphur ore processing depends on the efficiency of technology conversion and regional resource endowment. Under the combined effect of ore purchase prices, transportation costs and environmental protection costs, technological innovation is gradually narrowing the cost gap. To promote the sustainable development and utilization of low-grade and complex bauxite resources in China, it is necessary to give full play to the strategic role of the national "the Belt and Road" initiative. It is suggested to build a multi-level bauxite resource guarantee system, optimize the import strategy, realize the coordinated development of domestic resource development and international resource supply, improve the bauxite resource guarantee ability from the source, and provide solid resource support for the sustainable development of the aluminium industry.

6. References

1. Zhang Yanping et al. The current situation and development suggestions of bauxite resource utilization in China, *Journal of Mineralogy*, 2012, 32(1): 210–211.
2. Zhang Anchao et al. Analysis of Mineral Processing Technology for Bauxite Resources, *Henan Metallurgy*, 2009, (17): 20–21, 42.
3. Feng Qiming et al. Mineral Processing Practice of Bauxite, *Metal Mines*, 2008, (10): 1–4, 12.
4. S. Buentenbach et al. Mineral Processing of Bauxite, *Mineral Processing of Foreign Metal Mines*, 2008, (2): 34–37.
5. Wang Mingming et al. Experimental study on suspended state roasting desulphurization of high sulphur bauxite, *Non-metallic Ores*, 2022, (5): 6–9.
6. Gaolan et al. Characteristics and Potential Analysis of Bauxite Resources in China, *Chinese Geology*, 2015, (4): 853–863.
7. Li Wangxing. *Theory and Process of Alumina Production*, Central South University Press, 2010.
8. Si Jianmei et al. Background analysis and suggestions for Chinese enterprises' overseas investment in bauxite, *Light Metals*, 2018, (8): 1–3.

9. Liu Yulin et al. Research progress on the characteristics and comprehensive utilization technology of bauxite resources in China, *Mineral Protection and Utilization*, 2022, (6): 106–114.
10. Ling Shisheng et al. Overview of Physical Mineral Processing and Desilication Research on Bauxite, *Foreign Metal Mineral Processing*, 2006, (7): 9–12.
11. Ma Junwei et al. Experimental study on washing and desilication of trihydrate bauxite in Vietnam, *National Mineral Processing Academic Forum*, 2011: 62–65, 78.
12. Yu Xinyang et al. Experimental Study on Desilication, Purification and Beneficiation of a Low-grade Laterite Bauxite, *Non-metallic Minerals*, 2015, 38(1): 48–51.
13. Li Mingxiao et al. Research on flotation desilication and upgrading of low-grade bauxite, *Non-metallic Ores*, 2022, 45(3): 66–69.
14. Zhou Jieqiang et al. Research on the technology of reverse flotation desulphurization and desilication of a certain bauxite mine in Chongqing, *Mining and Metallurgy Engineering*, 2022, (01): 61–63, 67.
15. Mohammad Zarbayani et al. Mineralogical and sink-float studies of Jajarm low-grade bauxite, *International Journal of Minerals, Metallurgy and Materials*, 2010, 17(3): 251–256.
16. Xie Haiyun et al. Research on the combined classification and desilication of high alumina and high silica bauxite through gravity separation flotation, *Nonferrous Metals (Mineral Processing Section)*, 2018, (5): 53–57.
17. Jiang Zhengshuai et al. Research on efficient desulphurization and desilication process of low-grade bauxite, *Nonferrous Metals Science and Engineering*, 2022, 13(3): 26–34.
18. Luo Lin et al. Study on pre-desilication process and process dynamics of high silicon one water hard aluminium bauxite roasting, *Central South University*, 1997.
19. Qiu Tingsheng et al. Desilication technology for bauxite and its development status, *Mining Machinery*, 2015, 43(4): 8–13.
20. Zhou Guohua et al. A brief discussion on biological mineral processing of bauxite, *Comprehensive Utilization of Mineral Resources*, 2000, (6): 38–41.
21. Zhong Chanjuan et al. Directional screening and desilication performance of bauxite desilication microorganisms, *Chinese Journal of Geology*, 2013, (4): 692–699.
22. Liu Yan et al. Overview of Sulphur Hazards in High Sulphur Bauxite and Desulphurization Methods, *Northeastern University*, 2010.
23. Zhang Xin et al. Research status and development trend of desulphurization technology for high sulphur bauxite, *Nonferrous Metals (Smelting Part)*, 2022, (4): 20–27.
24. Liu Xijun et al. Experimental study on desulphurization of high sulphur bauxite by roasting, *Mining and Metallurgical Engineering*, 2017, (2): 112–115.
25. Ma Xingfei et al. Research on Low Temperature Roasting and Desulphurization of High Sulphur Bauxite with High Grade, *Nonferrous Metals (Smelting Section)*, 2021, (6): 32–36.
26. Yang Qian et al. Microwave roasting desulphurization pretreatment and high-pressure leaching performance of high sulphur bauxite, *Nonferrous Metals Science and Engineering*, 2021, (5): 39–45.
27. Wang Zhenjie et al. Experimental study on flotation desulphurization of a high sulphur bauxite mine in Guizhou, *Mining and Metallurgical Engineering*, 2020, (5): 39–41.
28. Li Shaoying et al. Experimental study on flotation desulphurization of a high sulphur bauxite mine in Guizhou, *Light Metals*, 2020, (11): 1–3.
29. Chen Hongde et al. Optimization of flotation desulphurization process conditions for bauxite covered by coal bearing strata, *Light Metals*, 2022, (4): 1–5.
30. Wu Guoliang et al. Industrial experimental study on flotation desulphurization of high sulphur bauxite under coal, *Light Metals*, 2019, (7): 8–12.
31. Hu Xiaolian et al. Study on the removal of sulphur from sodium aluminate solution by wet oxidation method, *Journal of Central South University (Natural Science Edition)*, 2011, (10): 2911–2916.

32. Qin Zhihui et al. Research on Strengthening Oxidation to Remove S^{2-} from Sodium Aluminate Solution, *Mining and Metallurgy Engineering*, 2016, (1): 101–103.
33. Liu Long et al. The Effect of Zinc Oxide on the Desulphurization of High Sulphur Bauxite Leaching Process under Optimized Conditions, *Nonferrous Metals: Smelting Section*, 2017, (1): 28–31.
34. Liu Zhanwei et al. Digestion behaviors of sulphur-containing minerals and desulphuration during alumina production process, *Minerals Engineering*, 2021, (173): 107234.
35. Zhou Jikui et al. Experimental study on bacterial oxidation of pyrite in high sulphur bauxite, *Metal Mines*, 2011, (12): 67–69.
36. Hao Yuepeng et al. Study on Impurity Sulphur in Bacterial Leaching of High Sulphur Bauxite, *Light Metals*, 2014, (10): 11–15.
37. Li Shoupeng et al. Synergistic removal of sulphur from high sulphur bauxite by moderate thermophilic bacteria, *Chinese Journal of Nonferrous Metals*, 2016, (11): 2393–2402.