Driving Forces and Pathways for China's Alumina Quality Upgrade

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Abstract

Alumina, the key raw material in aluminium production, directly determines the purity of primary aluminium and also influences the energy efficiency of the electrolysis process. As the world's largest producer of alumina, China's efforts to improve product quality are influenced by multiple factors, including resource characteristics, technological limitations, and policy promotion. Historically, due to China's bauxite resources being predominantly diaspore with high silica and low iron content, the production process relied heavily on the energy-intensive sintering process and parallel-series process. This resulted in alumina products being predominantly in floury form for an extended period. By the late 20th century, with the introduction of the Bayer process from Pechiney and the import of gibbsitic bauxite, China started to gradually achieve the production of sandy alumina. Nevertheless, due to various factors, China's alumina products remain primarily intermediate, hardly meeting the stringent requirements of the electrolytic aluminium industry for reduced energy consumption. In recent years, the Chinese government has introduced a series of policies requiring the aluminium industry to maximise energy consumption reduction, which in turn has driven improvements in the quality of alumina. However, in the alumina market, high-quality products have not received a corresponding price premium over the long term, leading some refineries to prioritize low quality and increased liquor productivity to boost profits. Looking ahead, the alumina industry needs to achieve breakthroughs in multiple aspects: First, leveraging the pressure from the aluminium industry for optimising energy consumption will promote the production of higher quality alumina. Second, addressing raw material supply bottlenecks through strategic overseas bauxite resource sourcing. Finally, establishing and refining a quality grading system for alumina to facilitate the industry's transition toward a quality-and-efficiency-driven model.

Keywords: Alumina, Bauxite, Electrolytic aluminium, Quality grading.

1. Introduction

Alumina, the key raw material for aluminium electrolysis, has a direct impact on the purity of primary aluminium and also influences the energy efficiency of the electrolytic process. Against the backdrop of the global green and low-carbon transition, the physical properties and chemical composition of alumina have become key constraints in upgrading electrolytic aluminium technology. As the world's largest producer of alumina and primary aluminium, China's evolution in product quality reflects the complex interplay of resource endowment, technological breakthroughs, and policy drivers.

China's alumina industry dated back in the 1950s. However, constrained by the characteristics of domestic bauxite resources where over 80 % are diasporic with high silica content [1], early alumina production relied on energy-intensive sintering process and parallel-series process. This resulted in alumina products being predominantly of the floury type for a long period, exhibiting defects such as high fine-particle content, poor flowability, and slow dissolution.

Since the 20th century, China's alumina industry has experienced significant development, with sandy alumina gradually being part of the industrial production landscape. However, influenced by market demand, China's products remain predominantly intermediate alumina. Key indicators such as the -45 µm content and α-Al_2O_3 proportion lag behind those of sandy alumina, making it difficult to meet the energy consumption reductions required from the aluminium industry.

In recent years, China has introduced a series of energy consumption limit standards and tiered electricity pricing policies for aluminium production, aiming to further reduce energy consumption in the aluminium industry. Given that the technology level of Chinese aluminium smelters has already reached the world's leading level, improving the quality of alumina can help achieving the goal of energy consumption reduction.

2. Development History of China's Alumina Quality

The quality of alumina, both physical properties and chemical composition, significantly impacts the quality of aluminium. Physical properties include particle size, attrition index, specific surface area, bulk density, α-Al_2O_3 content, angle of repose, etc. Chemical composition (purity) is a major factor, influencing the quality of primary aluminium and also affecting the technical and economic indicators of the aluminium electrolysis process. Since the establishment of China's first alumina refinery in 1954, the country's alumina industry has achieved significant development, with production technologies progressing through stages including the sintering process, Bayer-sintering series process, and Bayer process. The quality of alumina products has also evolved through three phases: an early stage dominated by floury alumina, a middle stage marked by the exploration and improvement of sandy alumina technology, and the most recent phase featuring further quality enhancement of alumina, driven by two-stage precipitation technology by mainly using imported bauxite.

The floury alumina contains over 20 % fine particles smaller than 45 µm, with α-Al_2O_3 accounting for 60–70 % of its composition. It exhibits a specific surface area of 50–60 m^2/g but weak adsorption capacity. Additionally, the floury alumina has an angle of repose > 40°, resulting in low particle strength and severe dust losses during electrolysis [2].

Sandy alumina typically exhibits superior physical and chemical properties. It has an average particle size of 80–100 µm, a fine particle content (- 45 µm) of less than 12 %, a high γ-Al_2O_3 proportion (and conversely an α-Al_2O_3 content lower than 20 %), and a specific surface area of 50–60 m^2/g. Additionally, sandy alumina demonstrates high flowability (angle of repose of 30–35°) and a low attrition index (< 20 %) [2].

The intermediate alumina exhibits properties between sandy and floury alumina, with a fine particle content (- 45 µm) of 12–20 %, a high α-Al_2O_3 proportion (40–50 %), and an angle of repose of 35–40° [2].

Table 1. Quality classification of SGA products [2].

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