Fresh Alumina Unloading and Conveying for Large-Scale Aluminium Electrolysis Projects

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Abstract

Driven by the "Dual Carbon" policy and the high-quality development of the aluminium industry, the selection of bulk material conveying solutions is crucial to the economic and environmental performance of aluminium electrolytic projects. This paper focuses on the unloading, storage, and conveying of fresh alumina in large-scale aluminium electrolytic projects. By comparing and analysing key indicators such as conveying capacity, construction investment, operating costs, and alumina attrition rate, a technical solution centred on bulk unloading, storage in spiral-rimmed steel silos, and hyper-dense phase conveying or belt conveying is proposed. Taking into account the impact of alumina on electrolytic production, comprehensive economic benefits and labour productivity, this solution has obvious technical and economic advantages over traditional solutions and has broad prospects for industry promotion.

Keywords: Electrolytic aluminium project, Bulk unloading, Steel silo storage, Hyper-dense phase conveying, Belt conveying.

1. Introduction

Under the guidance of the "dual carbon" strategy, electrolytic aluminium, as an important pillar industry of the national economy, is undergoing a profound transformation and upgrading towards low carbon and intelligence. At present, China's electrolytic aluminium industry is showing a trend of regional cluster layout and intelligent upgrading of technical equipment, with the core goal of focusing on energy conservation, carbon reduction, cost reduction and efficiency improvement. Alumina is the main raw material for electrolytic aluminium production, and the choice of its transportation scheme directly affects production indicators, economic benefits and environmental benefits. This puts higher demands on the quality control of alumina—not only must it meet the strict requirements of the electrolytic process on particle size distribution and specific surface area [1], but it must also ensure its physical stability during unloading, transportation and storage.

Research shows that the physical properties of alumina (such as particle size and morphology) significantly affect its dissolution rate and current efficiency in the electrolytic cell, while the stability of the particle morphology is related to the adsorption efficiency of pollutants such as hydrogen fluoride in the purification system [2]. However, the design of alumina conveying system faces many technical challenges, especially when balancing different transportation modes (road/rail) and conveying processes (such as hyper-dense phase pneumatic conveying, belt conveying [3]), it is necessary to take into account low attrition rate, high environmental protection and operation economy.

This paper takes a large-scale electrolytic aluminium project as a case study and focuses on the unloading, storage and conveying scheme of market-purchased alumina. By combining theoretical calculation with engineering practice, the bagged and bulk transportation modes are compared and analysed, and the comprehensive performance of core process systems such as hyper-dense phase conveying and belt conveying is evaluated, and finally an optimized solution with both economic and environmental benefits is formed. The research results can provide important technical references for similar large-scale engineering projects and help the green development of the electrolytic aluminium industry.

2. Brief Description of the Main Systems

2.1 Packaging System

The packaging method of alumina has evolved from "disposable packaging bags" to "recycling bag packaging" and then to "bulk de-packaging". At present, efficient logistics modes such as bulk shipping by car or train and container transportation have become the mainstream [4]. "Bulk-to-packaging" not only eliminates packaging, lifting, stacking, and unpacking, significantly improving logistics efficiency, but also effectively reduces loading and unloading costs and labour costs (the cost per tonne of alumina can be reduced by approximately 20 yuan). It also addresses the problem of packaging bag consumption and alumina dust generation at the source.

As a result, "bulk-to-packaging" has become the preferred mode of alumina transportation for large-scale aluminium smelters, offering significant operating cost advantages and environmental benefits, marking a new era of green and efficient alumina transportation.

2.2 Storage Solutions

Bagged alumina is typically stored in warehouses or silos, while bulk alumina primarily relies on large-scale storage silos. Traditional large-scale alumina storage silos primarily include concrete silos and welded steel silos. Concrete silos are expensive and have a long construction period, while welded steel silos have issues such as thick walls, high steel consumption, high construction costs, and the tendency for misalignment, limiting their application.

Drawing on the successful experience of spiral rolled steel plate silos in the building materials industry, it was introduced into the field of alumina storage, and technical optimization was carried out based on the material properties of alumina (such as fluidity and repose angle) [5]. This type of silo uses a spiral rolled edge interlocking structure, forming continuous spiral reinforcement ribs on the outside of the cylinder, which has both structural connection and overall reinforcement functions, significantly improving the strength and rigidity of the silo body, while reducing the steel structure engineering volume by about 30 %. This technology effectively solves the problems of small effective storage capacity, high investment, complex construction, and long construction period in traditional alumina storage silos, and has good technical applicability and economic benefits.

2.3 Transportation Solution

Traditional alumina transportation mostly uses dilute phase pneumatic conveying technology, but due to its severe wear, high alumina attrition rate, high energy consumption, and limited transportation capacity, it is difficult to meet the needs of modern large-scale electrolytic aluminium smelters [6]. At present, the mainstream conveying methods applicable to large-scale electrolytic aluminium projects are hyper-dense phase conveying [7, 8] and belt conveying [9]. Hyper-dense phase pneumatic conveying uses fans to supply air to drive pneumatic chutes (or sending tanks), so that powdered materials are fluidized and moved forward at a low speed. Its

3) Both hyper-dense phase conveying and belt conveying are new generation high-efficiency conveying technologies suitable for large-scale electrolytic aluminium projects. Hyper-dense phase conveying has advantages in system sealing, alumina attrition rate control, and automation level; belt conveying (especially air cushion belt type) has outstanding performance in conveying capacity and operating efficiency. The selection of specific solutions should be based on the actual needs of the project (such as conveying distance, terrain height difference), site conditions, and comprehensive economic indicators.

Table 1. Key technical and economic comparisons.

Project	**Unit**	**Hyper-dense phase Conveying**		**Belt Conveying**		**Remarks**
		Under-ground Chute	**Overhead Chute**	**Under-ground Belt**	**Overhead Belt**	
Technical Parameters						
Primary Aluminium Production Capacity	kt/a	500	500	500	500	
Alumina Consumption	t/d	2630	2630	2630	2630	
Unloading and Conveying Capacity	t/h	240	240	350	350	
Effective Operating Time	h/d	11.0	11.0	7.5	7.5	
Labor Requirements	People	4	4	4	4	
Construction Investment	Million RMB	39.30	40.30	41.10	40.50	
Construction Project	Million RMB	3190	3290	3170	3130	
Equipment Purchase and Installation	Million RMB	7.40	7.40	9.40	9.20	
Operating Costs	Million RMB/a	2.92	2.97	302	298	
Power (Electricity)	1000 RMB/a	25.2	25.2	21	21	Electricity : 0.35 RMB/kWh
Wages and Benefits	1000 RMB/a	600	600	600	600	150,000 RMB/year per capita
Equipment Maintenance	1000 RMB/a	180	180	230	220	Calculated at 3% of the equipment price
Depreciation	Million RMB/a	1.89	1.94	1.98	1.95	

5. References

1. Kou Fan, Cang Xianghui, Li Rongzhu. Effect of alumina particle size on its physical properties [J], Light Metals, 2019(2), 15–17(in Chinese) .
2. Pi Jianqing, Wang Mingli, Yang Ruyi, et al. Research progress in particle wet classification technology and precise classification of aluminium hydroxide [J], Journal of Process Engineering, 2024, 24(6), 647–659.

3. Liu Changsong. Discussion on the selection of alumina transportation design scheme for an electrolytic aluminium project [J], World Nonferrous Metals, 2020(13), 4-6.
4. Liu Tao, Jing Chao, Wan Tao, et al. Research on key technologies for top-loading and bottom-unloading bulk alumina powder railway transportation [J], Locomotive and Rolling Stock Technology, 2024, 60(1), 15–19.
5. Wu Huifang, Zhao Xiaokun, Lu Fang, et al. Application of new steel silos in alumina industry [J], World Nonferrous Metals, 2022(5), 154–156.
6. Niu Wenwei, Discussion on alumina conveying technology for large-scale aluminium electrolysis production [J], World Nonferrous Metals, 2014(1), 36–38.
7. Zhang Nianling, Gao Jinqiang, Zhang Yanhui, et al. Selection of alumina conveying method [J], Light Metals, 2011(S1), 239–242 (in Chinese).
8. G. Girault et al., Recent developments in hyper-dense phase alumina handling systems, TMS Light Metals 2016, 493-498.
9. Zou Zhiyong, Sun Kangjian. Application of air cushion belt conveying technology for alumina in large-scale aluminium electrolysis series [J]. Light Metals, 2011(S1), 234–238 (in Chinese).