Application of Intelligent Crust Breaking Cylinders in Aluminium Electrolysis

Zhenbao Li
Onsite Technician
Guangxi Hualei New Materials, Pingguo, Guangxi
Corresponding author: 1509319586@qq.com
https://doi.org/10.71659/icsoba2025-al044

Abstract

As a core actuator in aluminium reduction cells, the breaking cylinder system plays a critical role in breaking the crust formed by the electrolyte. Current pneumatic system designs face issues such as delayed valve response, significant pressure loss in compressed air, and high-temperature creep failure of sealing components. To effectively improve the performance of the crust breaking cylinders, technicians have optimized the pneumatic system design by installing a custom rope sensor on the cylinder, which is reliably connected to the crust breaking cylinder using a specially designed connector. This enables precise closed-loop control of the cylinder's operation. A large-bore shut-off control valve is also used, characterized by rapid switching, high flow capacity, excellent stability, and strong dust resistance. These optimizations enhance both the efficiency and quality of aluminium electrolysis production.

Keywords: Electrolytic cell, Intelligent crust breaking, Crust breaker cylinder.

1. Current Status of Crust Breaking Technology

As a key link in the aluminium reduction cell production process, crust breaking technology is limited by design flaws in the current pneumatic systems. At present, although the crust breaking cylinder system – being the core actuator of the aluminium reduction cell – plays an essential role in breaking the crust of the electrolyte, its performance is constrained by multiple factors.

1.1 Research Background and Significance

In the aluminium electrolysis production process, electrolytic cells serve as core equipment, and their operational efficiency and stability are directly related to the production capacity of the entire line. As a key actuator in the electrolytic cell, the breaking cylinder system undertakes the critical task of breaking the crust formed by the electrolyte. Its performance directly impacts the efficiency and energy consumption of the cell. However, the current pneumatic system design suffers from several shortcomings, such as delayed response of reversing valves, large pressure losses in compressed air, and creep failure of sealing components under high temperatures. These issues not only limit the performance of the crust breaking cylinder but also increase energy consumption and production costs in aluminium electrolysis.

With the continuous development of the aluminium electrolysis industry, demands for higher production efficiency and product quality are increasing. Therefore, optimizing the pneumatic design of the crust breaking cylinder system to enhance its performance has become an urgent issue for the aluminium electrolysis industry. This study aims to reduce the energy consumption of the crust breaking cylinder system and to improve production efficiency by optimizing the pneumatic system, adding custom rope sensors for precise closed-loop control, and adopting a large-bore shut-off control valve to improve response speed and stability [1].

The implementation of this research not only helps address the existing problems in crust breaking cylinder systems in aluminium electrolysis, improving the operational performance and stability of the cells, but also supports energy conservation, emission reduction, and sustainable development in the aluminium electrolysis industry. Furthermore, the widespread application of the research outcomes will help drive technological progress and industrial upgrading in the aluminium electrolysis sector, enhancing the overall competitiveness of China's aluminium electrolysis industry. Thus, this study holds significant theoretical and practical value.

1.2 Existing Technologies of Crust Breaking Cylinders

The following are some existing cylinder technologies used in electrolytic cells:

1) A purely pneumatic-loop breaking cylinder uses compressed air to drive the piston in a linear reciprocating motion. Its core components include the cylinder body, piston, piston rod, sealing rings, and cylinder head. The cylinder body is typically made of aluminium alloy or stainless steel. The piston moves the rod by compressing and releasing air, while the sealing rings ensure airtightness. Compressed air is controlled by a two-position five-way solenoid valve to enter the cylinder and drive the piston for the crust breaking action. Exhaust is handled through solenoid valve switching to complete the return stroke [2].
2) An electromagnetic reversing crust breaking cylinder uses a solenoid reversing valve to control the flow direction of compressed air, thereby driving the piston for reciprocating motion. The solenoid reversing valve shifts the spool position within the valve body using electromagnetic force to redirect airflow. When the solenoid is energized, the spool shifts to allow air to enter the cylinder from the lower end, driving the piston in the opposite direction and enabling bidirectional cylinder movement.

Although these cylinders have wide applications, conventional types are prone to issues such as seal wear in high-temperature and corrosive environments, leading to air leakage, breaker jamming, and delayed valve response.

This paper presents a new type of intelligent breaking cylinder that effectively addresses problems like poor sealing and breaker jamming. Together with a series of associated control systems, it significantly enhances production efficiency.

1.3 Current Research on Crust Breaking Cylinders

Through the implementation of this project, we are able to effectively solve the issue of crust adhesion during the breaking process and significantly reduce the consumption of compressed air. Additionally, by leveraging the collected detection signal data and the developed application software, the crust breaking and feeding system can be precisely guided and optimized to improve stable production operations.

2. Application of Intelligent Crust Breaking Cylinder

2.1 Components of Intelligent Crust Breaking Control

A new type of intelligent cylinder is used in combination with a pneumatic control cabinet and cell control unit to form the cell actuation control system (see Figure 1).

2.2 Intelligent Crust Breaking Cylinder

The new intelligent breaking cylinder consists of an intelligent sensor, control valve, intelligent control box, and related devices. The intelligent sensor is one of the most critical components of the new intelligent breaking cylinder, operating on the principle of high-precision measurement reduced production downtime caused by equipment failure, ensuring the continuity and stability of electrolytic production [4].

Table 1. Durability of sealing components in different cylinders.

Type	Creep Days of Sealing Components	Creep Days After Replacement
Test Cell 1	338	325
Test Cell 2	342	331
Test Cell 3	346	358
Average	342	338
Standard Cell 1	235	223
Standard Cell 2	228	241
Standard Cell 3	254	252
Average	239	238

3.3 Economic Returns

With intelligent breaking cylinders, the lifespan of sealing components was extended. Over a two-year period, the savings from avoiding one replacement cycle across 300 cells – each with six breaker cylinders and each sealing component costing 200 RMB (28 USD approx.) – amount to an estimated annual savings of 180 000 RMB (24.9 kUSD/y approx.).

The production of compressed air requires substantial electrical energy. In aluminium smelters, breaking cylinders typically operate continuously, so the significant reduction in compressed air consumption directly reduces energy usage. Moreover, the notable decrease in compressed air usage brings both direct and indirect economic returns to the smelter, serving as an effective measure in energy conservation, cost reduction, production efficiency improvement, and product quality enhancement, contributing significantly to sustainable development.

4. Conclusions

The application of intelligent breaking cylinders has shown remarkable results. It extended the service life of sealing components by over 40 %, significantly reduced compressed air consumption during the crust breaking, effectively reduced the maintenance workload for cylinders, and greatly enhanced the operational stability of electrolytic cells, making it highly worthy of broader implementation.

5. References

1. Jinshuo Zhang and Jinxian Liu, Application of Intelligent Crust Breaking System in 500kA Prebaked Anode Electrolytic Cells [J], *JiuGang Technology*, 2021(2), 59–62 https://www.doc88.com/p-17239045810339.html (in Chinese).
2. Ju Zhao, Research on Intelligent Control System for Alumina Accumulation in Electrolytic Cells [J], *Shanxi Metallurgy*, 2023, 46(08), 192–194. doi: 10.16525/j.cnki.cn14-1167/tf.2023.08.076 (in Chinese).
3. Junwei Wang, Design of a New Energy-Saving Crust Breaking Cylinder System for Electrolytic Cells [D], Henan University of Science and Technology, 2017 (in Chinese).
4. Chengyuan Li, et al. Application of Intelligent Crust Breaking System in Electrolytic Workshop [J], *Shandong Metallurgy*, 2023, 45(06), 62–64, doi: 10.16727/j.cnki.issn1004-4620.2023.06.013 (in Chinese).