Application Research of Nano-Ceramic-Based Anti-Oxidation Technology for Anodes and Stubs in Aluminium Electrolysis Cells

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Abstract

This paper conducts an anode anti-oxidation test by spraying nano-ceramic-based high-temperature anti-oxidation coating material on the surface of pre-baked anodes and stubs. The test lasted for five anode changing cycles (about half a year). The test results show that the long-term application of the anode anti-oxidation coating material can effectively reduce the oxidation of carbon blocks and stubs. It plays a significant role in maintaining the regularity of the anode shape. The coated anode can extend the anode changing cycle by one day compared with the uncoated anode. After long-term application, the anode anti-oxidation coating material has no side effect on the quality grade of aluminium.

Coated anode stubs increase smoothness of the stub surface and decrease the occurrence of “narrow neck”. The lifespan of the coated stubs can be extended by 2.9 times. The metal purity can significantly increase by reducing the iron content in aluminium by 280 ppm.

Keywords: Aluminium electrolysis cells, Anode anti-oxidation nano-ceramic-based coating, Anode stubs anti-oxidation nano-ceramic-based coating, Long-term industrial tests.

1. Introduction

At present, the aluminium industry production uses the cryolite-alumina molten salt electrolysis method, in which molten cryolite serves as the solvent and alumina as the solute. Using a carbon body as the anode, after passing a strong direct current, an electrochemical reaction occurs at both poles in the electrolytic cell at a high temperature of approximately 950 °C, i.e., electrolysis. The anodic oxidation products are mainly CO_2 and CO gases, which contain a certain amount of harmful gases such as hydrogen fluoride and solid dust [1]. These gases easily react with the carbon anode and steel stub at high temperatures, leading to the oxidative consumption of the carbon anode and the oxidative corrosion of the steel stub.

In recent years, the main anti-oxidation research on anodes and steel stubs has included: (1) Anode anti-oxidation: anode production process management, anode production formula and process anti-oxidation technologies, and coating material anti-oxidation technologies [2–6]; (2) Steel stub anti-oxidation: anode covering material management, anode steel stub protection rings (divided into residual pole powder, carbon, aluminium ash, alumina, metal-based, covering material-based protection rings), coating technologies, wrapping technologies, etc.[7–15]. Among these methods and technologies, the coating anti-oxidation technology has shown better application effects.

As a surface treatment anti-oxidation method, the nano-ceramic-based coating anti-oxidation technology is a newly emerging technology in recent years. The coating has the advantages of room-temperature curing, rapid drying, convenient construction, non-toxicity, high temperature resistance, excellent corrosion resistance, high hardness, good adhesion, and non-stickiness. As the temperature gradually increases, the coating material grains shrink and the crystal gaps decrease, completing pre-sintering at 400–500 °C. Finally, a high-strength and dense networkstructured sintered body is formed on the surfaces of the anode and steel stub. This sintered body can withstand high temperatures above 900 °C for a long time and resist the erosion of air, hydrogen fluoride gas, and high-concentration CO_2, ultimately achieving the purpose of preventing the oxidation of the anode and steel stub.

The author's paper published in ICSOBA 2023 [16] focuses on exploring the anti-oxidation mechanism of nano-ceramic-based anode anti-oxidation coating materials, conducting in-depth research on their anti-oxidation effect in different bath systems and pot types, and testing the impact of carbon block baking weight loss rate on anode anti-oxidation. It sets testing methods and application standards for such coatings, proving they can reduce aluminium reduction pot instability and improve primary aluminium quality, cutting anode gross consumption by 15–25 kg C/t Al and power consumption by 20–50 kWh/t Al.

This paper conducts a large-scale industrial application study on anode and steel stub anti-oxidation using the BY series nano-ceramic-based anti-oxidation technology [17, 18], aiming to provide data reference and economic accounting for the popularization and application of anti-oxidation coating materials for anodes and steel stubs.

2. Anode Anti-Oxidation Coating

2.1 Anode Anti-Oxidation Application Process

2.1.1 Industrial Tests

This long-term industrial application test was carried out on 400 kA electrolytic cells in an aluminium plant in Shaanxi. The test included 4 test cells (No. 4321, No. 4322, No. 4323, No. 4324) and 4 comparison cells (No. 4315, No. 4316, No. 4317, No. 4318). The test lasted for 5 anode changing cycles from 25 September 2019 to 15 March 2020 and the results of the long-term industrial application were continuously tracked.

The first test cycle (25 September–28 October): The anode changing cycles of both the test cells and the comparison cells were 34 days. Before the new anodes were put into the cells, the heights of the coated new anodes in the test cells and the uncoated new anodes in the comparison cells were measured. The main test purpose of this cycle was to gradually replace the uncoated anodes in the test cells with coated new anodes.

The second test cycle (29 October–1 December): The anode changing cycles of both the test cells and the comparison cells were 34 days. The dimensions (length, width, and height) of the butt anodes in the test cells and the comparison cells that were put into the cells in the first cycle were measured every day. The main test purposes of this cycle were: 1) to stabilize the cell condition and reduce the impact of the mixture of coated and uncoated anodes on the test results in the early stage; 2) to provide data basis for whether to extend the service cycle of the coated anodes in the third cycle by measuring the dimensions of the butt anodes in the test cells and the comparison cells.

The third test cycle (2 December–5 January): The anode changing cycle of the test cells was 35 days, and that of the comparison cells was 34 days. The dimensions (length, width, and height) of the butt anodes in the test cells and the comparison cells that were put into the cells in the second cycle were measured every day. The main test purpose of this cycle was to provide experimental data results for extending the service cycle of the coated anodes by measuring the dimensions of the butt anodes in the test cells and the comparison cells.

to extend the anode changing cycle by one day compared to uncoated ones. Additionally, its use on stubs can reduce their surface oxidation, enhance surface smoothness, and minimize the occurrence of the "narrow neck", thereby extending stub lifespan by 2.9 times. In large-scale smelters, the coating's ability to reduce oxidation and carbon dust deposition on anode carbon blocks has reduced carbon consumption and decreased anode cost per ton of aluminium.

Environmentally, the technology contributes to sustainability goals by curbing excessive carbon consumption. Additionally, the 280 ppm reduction in iron content in primary aluminium not only improves metal purity, but also reduces the need for post-production purification processes, further saving energy and reducing emissions.

Hunan Bable Material Technology Co. nano ceramic-based anti-oxidation coating materials, presented in this paper, are used in over a dozen smelters in China and sold to four smelters in Malaysia and India.

5. References

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