Application of Nano-Ceramic Anti-Oxidation Coating on Anodes of Aluminum Reduction Pots

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Abstract

Anodes are the heart of aluminium reduction pots. The reduction of anode oxidation and anode oxidation rate and the improvement of anode service life have always been a topic of great interest in aluminum reduction research. This article introduces the anti-oxidation mechanism of nano-ceramic-based anode anti-oxidation coating materials and presents: the results of in-depth research on the anode anti-oxidation effect of these materials in different bath systems and pot types; the testing of the impact of carbon block baking weight loss rate on anode anti-oxidation; and finally, a set of testing methods and application standards established for nano-ceramic-based anode anti-oxidation coatings. The recognition and application of this product in smelters have effectively reduced the instability of aluminum reduction pots, and also improved the quality of liquid aluminum. Practice has proven that this product can reduce the anode gross consumption by 15-25 kg/t Al and the power consumption by 20-50 kWh/t Al.

Keywords: Aluminium reduction pot anodes, Anode anti-oxidation nano-ceramic coating material.

1. Introduction

In a cryolite-alumina prebaked pot, the quality of carbon anodes has a direct influence on the production index of aluminum reduction. When the carbon anode fails to meet the quality requirement, it will generate abundant carbon residues in the bath and bring a series of hazards to pot [1-2]. To reduce carbon residues, high-quality carbon anodes must be used, and a careful operation and a meticulous process management must be adopted. As the availability of high-quality calcined coke decreases and the production costs need to be cut down, high-sulfur and high-vanadium cokes are widely used, resulting in poor anode quality and lower oxidation resistance, which have negative influence on aluminum production. In order to improve the oxidation resistance of anodes and reduce carbon residues, anode coating technologies have been extensively tested in China [3-6].

Currently, nano-ceramic-based anti-oxidation technology is the most widely applied anti-oxidation coating technology in China [7-8]. This technology involves the application of an anti-oxidation coating on the surface of a carbon anode, which has the advantages of being able to solidify at room temperature, quick drying, convenient construction, non-toxic, high-temperature resistance, excellent anti-corrosion performance, high hardness, good adhesion, non-stick, etc. Based on field data from different pot lines, this paper digs into the influence of the nano-ceramic-based coating on aluminum production index, so as to provide reference for application of this technology on a large scale [9-10].

2. Anti-oxidation Mechanism of Nano-Ceramic-Based Anode Coating

Nano-ceramic-based anti-oxidation anode coating mainly consists of a matrix, a solvent and an additive. The main components include:

- Alumina components: Al_2O_3, accounting for 45-50 % of the total mass of the coating.

- Alkali metal grain boundary fusion components: composed of plagioclase ore powder, albite, and sodium fluorosilicate, accounting for 2 to 3 % of the total mass of the coating.
- Silicone sol reinforcement components: silica sol, accounting for 25-30 % of the total mass of the coating.
- Continuous modification components of silane coupling agent: silane coupling agent, accounting for 0.3-0.8 % of the total mass of the coating.
- Crystal control components: composed of ytterbium(III) oxide and erbium(III) oxide, accounting for 0.001 % of the total mass of the coating.
- Flow control components: water, accounting for 16.2-27.7 % of the total mass of the coating.

Nano-ceramic-based anti-oxidation anode coating uses aluminum oxide as the basic structure skeleton, and silica sol as the reinforcing component to obtain the basic body with: dense structure, high strength, strong viscosity, self-healing. The alkali metal grain boundary fusion component, which constitutes of a certain proportion of plagioclase ore powder, albite, and sodium fluorosilicate, enables the basic body to be sintered at a low temperature of 400~420 ℃ to form a dense sintered body. At the same time, alumina is modified with silane coupling agents to improve the dispersion, stability, film-forming ability, heat resistance, and other properties of the coating components. By controlling the addition of components through crystal morphology, the high strength and toughness of the entire coating after sintering can be improved.

When nano-ceramic-based anti-oxidation anode coating is sprayed on the surface of an anode, as the anode temperature increases, the grain of coating material shrinks and the crystal gap decreases. Pre-sintering is completed at 400~500 ℃, and a high-strength and dense-network-structure sintered body is formed around the anode. The sintered body can withstand high temperatures above 900 ℃ for a long time, and can resist the carbon loss due to air, hydrogen fluoride gas, and high concentration CO_2, ultimately achieving the goal of preventing anode oxidation.

3. Anti-oxidation Tests for Different Pots and Bath Systems

The nano-ceramic-based anti-oxidation anode coating has been tested at multiple smelters ranging from 240~500 kA and in different bath systems including a pure bath system and a complex bath system. The testing result can be seen as Table 1 shows.

Table 1. Anode coating test results.

Test elements	Smelter 1	Smelter 2	Smelter 3	Smelter 4	Smelter 5
Current (kA)	240	300	400	500	500
Bath system	pure	complex	complex	pure	pure
Voltage (V)	3.96	3.99	3.97	4	3.99
Noise (mV)	17	19	18	18	20
Pot temperature (°C)	948	925	930	950	952
Anode carbon dioxide reactivity (%)	76	81	71	80	83
Anode cycle(day)	32	33	34	33	35
Quantity of test pot	10	4	4	48	37
Test period (months)	5	5	6	6	12
Reduction in carbon residues (%)	54	43	61	45	38
Extension in anode change schedule (day)	1.33	1	1.66	1	1

From Figure 5, it can be seen that the coating can reduce the iron content of aluminum produced. After one year, the iron content of coated sections is 0.01 % lower than that of standard sections. After applying the coating, the thickness, length, and the width of the butt in the coated sections were less consumed than those in the standard sections on the condition that the anode change cycle is extended for one day. As the thickness of the butt is relatively greater, the ability to resist scratching, melting, and bottom penetration is enhanced, and the iron content in the aluminum produced is reduced. At the same time, the stability of the pot in the coated sections is improved, and the pot cavity is more stable, which is also beneficial for improving the quality of the aluminum.

7. Conclusions

A technical standard has been established through tests on nano-ceramic-based anti-oxidation anode coating applied to different pot lines and bath systems.

The conclusions are as follows:

1. The anti-oxidation performance detection (baking losses) shall be less than 1.5 % for the nano-ceramic-based anti-oxidation anode coating to extend anode the change schedule for one day.
2. The application of nano-ceramic-based anti-oxidation anode coating has a positive effect on reducing noise level, power consumption, and gross anode consumption, as well as improving current efficiency and quality of aluminum produced.
3. The nano-ceramic-based anti-oxidation anode coating can reduce the gross anode consumption by 15-25 kg/t Al, and reduce the energy consumption by 20-50 kWh/t Al, which would generate economic benefits.

8. References

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