Induced Draft Forced Cooling Process for Anode Baking Furnace

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Abstract

In the context of the continuous large scale evolution of the anode baking furnace, the drawbacks of the traditional blowing draft forced cooling process (BD-FCP) have become increasingly prominent. This traditional method, which involves blowing hot air into the workshop, not only leads to a continuous rise in the production environment temperature, severely deteriorating the working conditions for workers, but also poses a significant threat to the stable and normal operation of equipment. To address these issues, this study proposes replacing the traditional BD-FCP with an induced draft forced cooling process (ID-FCP). In the new process, the hot air after heat exchange is efficiently evacuated from the workshop through the induced draft system for subsequent heat recovery. In the current work, advanced numerical simulation technology is utilized to conduct a comprehensive and in-depth comparative analysis between the two cooling processes. The calculation results indicate that the cooling rate of anodes in the ID-FCP is comparable to that in the BD-FCP. Additionally, the flue gas exhaust temperature of the induced-draft system can reach 150–230 °C, which satisfies the temperature requirements for heat recovery. Therefore, the ID-FCP can fully meet the cooling requirements of baked anodes, significantly reduce the ambient temperature in the workshop, and successfully recover waste heat during the baking forced cooling stage. This new process comprehensively contributes to energy consumption reduction in anode production, representing a promising technological innovation in this field.

Keywords: Anode for aluminium, Anode baking furnace, Combustion control system, Blowing draft forced cooling process, Induced draft forced cooling process

1. Introduction

The open-type ring baking furnace (BF) is the core production equipment for the high-temperature modification of green anodes in the carbon industry. The anode baking process is executed by the furnace combustion control system (FCCS) according to a pre-defined temperature ramp profile. Based on the control phases of FCCS over anode temperature evolution, the baking cycle is divided into four sequential stages: preheating phase, heating phase, natural cooling phase, and forced cooling phase.

The anodes in the furnace section are heated to approximately 1100 °C after the preheating and heating phases, then their physical and chemical properties will meet the requirements for electrolytic production. Prior to the discharge of high-temperature anodes from the furnace section, their temperature must be reduced to a reasonable level. To optimize production efficiency and economic viability, this temperature is set as the minimum value between the maximum permissible operating temperature of the discharge equipment and the minimum threshold to prevent anode oxidation. The temperature reduction is achieved through the natural and forced cooling phases.

During the natural cooling phase, cold air from the workshop is blown into the flue channels via blowing ramps, reducing the temperature of high-temperature anodes to approximately 600 °C. Meanwhile, the preheated cooling air is directed to the furnace sections in the heating phase for combustion support, enabling partial heat recovery. In the forced cooling phase, blowing ramps are also used to introduce cold workshop air into the flue channels for cooling. Unlike the natural cooling phase, the peephole covers above the flue channels in the forced cooling area are opened, allowing cold air to discharge heat from the flue channels through the open peepholes into the workshop. This lowers the anode temperature below 300 °C [1], making the anodes ready for discharge.

2. Problems of Traditional Forced Cooling Processes

During the forced cooling phase, cold air from the baking workshop is blown into the flue channels by blowing ramps. After heat exchange, the air flows out through the furnace-top peepholes and dissipates into the workshop, transferring substantial heat from the furnace to the workshop environment and raising the ambient temperature. With the continuous development of larger-scale baking furnaces, the physical size of baking workshops has increased, exacerbating the problem of excessive ambient temperatures. In some sites, peak temperatures can exceed 70 °C in summer, not only deteriorating the working environment for operators but also causing malfunctions in equipment such as the cranes and combustion control systems, which disrupts normal production. This has become a significant challenge plaguing the baking workshop operations.

From the perspective of heat balance [2], before anode blocks enter the cooling stage, heat stored in the furnace, heat carried away by packing materials, and heat carried away by baked anodes account for 80 % of the total heat expenditure. Upon entering the natural cooling zone, a portion of the heat re-enters the system through preheated air, while another portion dissipates through the furnace surface. In the forced cooling furnace sections, the majority of the heat is transferred into the baking workshop via forced cooling, with the remaining heat retained in the refractory materials, anode blocks, and packing materials. Typically, the temperature in natural cooling furnace sections drops from approximately 1100 to 700 °C, and that in forced cooling furnace sections decreases from 700 to around 300 °C. Therefore, it can be estimated that about 20 % of the total heat input, equivalent to approximately 1.5 GJ/t of anode, is carried into the baking workshop by the cooling air in the forced cooling zone. Based on the heat balance, the heat dissipation from the entire baking furnace surface is estimated to account for around 20 % of the heat input. This analysis reveals that the excessively high temperature in the baking furnace workshop is caused not only by heat dissipation from the furnace surface but also by the release of hot air in the forced cooling zone.

To address the above issues, the study proposes a process route that replaces blowing ramps with induced-draft ramps during the forced cooling phase. Cold air is drawn into the flue channels through peepholes to cool the anodes, and the heated air is discharged from the workshop via an induced-draft system for heat recovery. The induced-draft system comprises an induced draft ramp, insulated conveying pipelines, and a medium-low temperature flue gas waste heat recovery system. The induced draft ramp shares structural similarity with the currently employed blowing ramps, albeit with induced draft fans substituting for blowers. The induced draft ramp traverses along the baking furnace floor in conjunction with the firing system operation. One end of the induced draft ramp adjacent to the ring main functions as its smoke exhaust port, which is

- Utilization for hot water production or winter heating in carbon block warehouses in northern regions.

5. Conclusions

This study establishes a numerical simulation model for the forced cooling phase of an open-loop ring baking furnace, validated by test data for calculation accuracy. Through theoretical calculations and comparative analysis of BD-FCP and ID-FCP using numerical simulation, the results show:

1. The ID-FCP combustion control system can reduce the final anode cooling temperature to below 300 °C. Throughout the 4C–7C stages, the maximum anode cooling rate does not exceed BD-FCP computational data, meeting production process requirements and confirming ID-FCP feasibility.

2. The ID-FCP exhaust gas temperature exceeds 150 °C, satisfying the lower limit for low-temperature waste heat recovery. This enables comprehensive reduction of baking energy consumption and addresses the high-temperature issue in baking workshops during summer.

6. References

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