Thermal Conductivity Measurement and Heat Loss Analysis of Anode Cover Material for Aluminium Reduction Cell

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Abstract

In an aluminium reduction cell, more than half of the heat loss is dissipated through the anode and the top cover. The thermal resistance of the anode cover is a key component. This paper proposes to measure thermal conductivity of the cover material using plate thermal conductivity meter to guide the design and operation of the aluminium reduction cell. The authors sample and test the thermal conductivity of the crushed cover material and fresh alumina powder on the anode, and compare the thermal conductivity of the cover materials with different particle sizes, and analyze the temperature and heat dissipation of different anode cycles. At the end, some suggestions are made on the selection of the particle size, composition ratio and thickness of anode cover material in the aluminium reduction cell operation, and a new method of anode covering is proposed.

Keywords: Aluminium reduction cell, Anode top heat loss, Anode cover material, Thermal resistance.

1. Introduction

Thermal equilibrium of an aluminium reduction cell is mainly related to the temperature field distribution of each part of the cell. The temperature field has a direct influence on the service life of the cell: over-insulation will cause poor cell ledge and lead to side corrosion and early failure while weak insulation may result in a thick cell ledge and put too much pressure on the cell. During cell operation, a 120–200 mm cover mainly composed of crushed bath and alumina, should be laid on the anode. This work can be done manually or by crane. The anode cover has three main functions: to adjust and control the cell thermal equilibrium, prevent anode oxidation and serve as the first barrier against hydrogen fluoride emission.

However, there are some problems in the anode cover management during operation, such as: too long time for anode changing which makes it hard to achieve standardized control; the laying of cover material is completely controlled by workers and the thickness of the cover material is uneven, resulting in poor thermal insulation uniformity; the replacement of butt will generate heat loss, and the new anode cover will absorb heat too when it enters the operation process.

Therefore, a better understanding of anode cover characteristics and a standardized anode cover method would help to improve heat dissipation distribution and maintain a good thermal equilibrium condition for cells. Smelters have different methods for anode cover; some lay cover material on the new anode before anode change, and then move the new anode and its cover to the cell simultaneously; others replace the anode first and lay cover material a few hours later.

In this experiment we took samples of cover material and alumina from two smelters and compared the thermal conductivity of cover materials with different particle sizes. In this paper, the authors intend to analyze anode cover from the perspective of heat dissipation of cell, optimize the ratio and the laying method of the cover material through a thermal conductivity test. The goal is to seek a better operational solution to maintain the energy balance of the aluminium reduction cell.

2. Analysis on Heat Loss from Cell Upper Structure

The heat loss from the upper part of the cell accounts for more than 50 % of the total heat loss. The thickness of the thermal insulation material has a decisive influence on the heat loss of the upper cell. Therefore, a stable and uniform heat insulation layer is crucial to maintaining the energy balance of the cell. At present, a common problem for Chinese prebaked cells is an insufficient heat insulation material. Obviously, the thinner the heat insulation material is, the higher the ratio of heat loss from the top of the cell to the total heat loss, and changes in the material surface are more likely to cause changes in the energy balance (or thermal equilibrium), so the stability of cell gets worse. The typical heat loss of modern aluminium reduction cells is roughly as follows: more than 50 % of the heat is dissipated from gas, hood and upper structure after passing through the anode cover material, and around 40 % is dissipated from the side and end of the cell, and only less than 10 % is dissipated from the bottom of the cell [1].

The heat loss of the cell can be divided into two regions, as shown in Figure 1 below.

Region A: due to the crust and leg on the side of the cell, the temperature at the interface between the crust and the cell is constrained by the initial crystal temperature of the bath. Therefore, the heat loss from the cell shell relates to the heat loss of the bath superheat (T_{bath}-T_{liq}).

Region B: it is related to the heat loss transmitted under bath temperature condition.

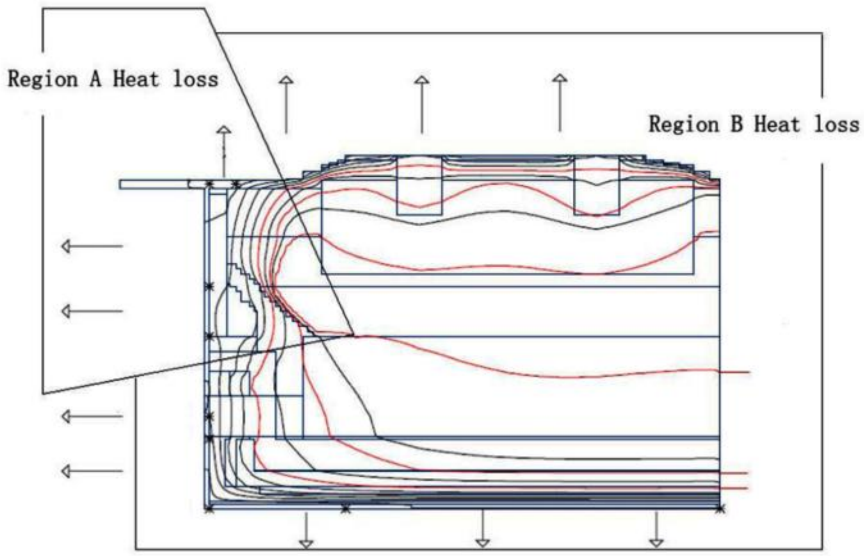

Figure 1. Two regions of heat loss in the aluminium reduction cell.

The thermal resistance of the upper part of the cell mainly consists of three parts: the convection heat transfer resistance of bath and anode, the thermal conductivity resistance of the anode and cover material, and the convection heat transfer resistance of the cover material and gas. The total thermal resistance of the upper cell is shown in the following equation:

In addition, Table 1 shows the measured data of anode cover with different heights. When anode cover height drops from 180 mm to 150–160 mm, the temperature change is twice as big as before with the same anode consumption (i.e., same anode height) with an absolute temperature difference between 140 and 280 °C.

From the comparison of these two aspects - the surface temperature measurements of different anode heights and of different anode covers - it can also be seen that the change in anode cover height has a greater impact on the temperature of the anode cover surface.

5. Conclusions

In the current aluminium reduction operation, the anode cover layer has a significant impact on the thermal equilibrium and energy balance of the cell. The composition of the anode cover layer is a mixture of bath and alumina particles of different sizes. Due to the lower thermal conductivity of alumina compared to bath particles, to reduce the heat loss of the cell, the ratio of alumina in the cover layer can be increased. Also, the thickness of the cover layer can be increased.

The cover is mainly added manually or by crane. However, it is difficult for smelters to maintain standardization of anode cover for a long time. Therefore, the next step is to develop a reusable anode cover and related device. A new anode cover method and device would be beneficial for smelter construction, as it can reduce the construction investment and operating costs of crushing, conveying and feeding systems. Also, it would be helpful for smelter management, as it can reduce the workload and time required to maintain the operations (breaking, laying, and edge trimming) for existing anode cover work.

6. References

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