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Heat Exchanger for Alumina Preheating in Aluminium Reduction Cells

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Abstract

The raw materials supplied to the aluminium reduction cell need to achieve the process temperature of around 960 °C. The most relevant heat up energy requirement is used to bring alumina temperature from the potroom to the process temperature, consuming around of 0.56 kWh/kg Al. Reducing the process energy requirement by recovering some of the energy loss is fundamental if one is seeking ways to reduce cell specific energy consumption.

One major share of energy wasted at the aluminium reduction cell process is through the hot off-gas collection. A heat exchanger designed to preheat the alumina by using the heat of the gases generated by the reduction process is presented. This device can be used in existing point-feeder prebake cell technologies. Numerical models were used to predict how much energy can be recovered. Around of 0.30 kWh/kg Al of direct heat recovery is predicted using the heat exchanger to preheat alumina. Indirect beneficial side effects open the possibility for a total energy consumption reduction of 1.2 – 1.5 kWh/kg Al.

Keywords: Aluminium electrolysis cells, energy consumption, alumina preheat, energy recovery.

1. Introduction

Reducing the specific energy consumption of aluminium reduction cells is one of the greatest goals of nowadays light metals industry. There are many energy recovery opportunities in the cell that are been employed in smelters. Usually, heat recovery methods and devices [1 – 5] are proposed using the wasted cell energy to heat up an external fluid, and then the thermal energy can be employed in other applications. Sometimes, the heat exchanger has other objectives beyond energy recovery such as decreasing the off-gas temperature before the GTC [2] and the improvement of the emissions capturing efficiency. Other works propose to use wasted energy to heat up the raw materials. Anode preheat is proposed in paper [6] and patent [10] and advantages on the anode current pickup are reported [6].

The concern about alumina preheating has already been seen in earlier publications. US patent 3,006,825 presents an alumina feeder wherein the alumina is preheated by the burners' off-gas in Søderberg cells; the gases passing through an alumina fluidized bed [11]. The feeder disclosed in the US patent 3,371,026 is claimed to have the ability to preheat the alumina before feeding [12].

The Distributed Pot Suction was implemented by Hydro [7, 8], achieving reductions in overall pot off-gas flow, reducing the top energy loss while increasing the gas temperature. This enabled their pots to operate below 11.8 kWh/kg Al [9]. The reported energy saving by using localized gas suction reached up to 0.4 kWh/kg Al. The overall effect might be smaller because the energy loss through other parts of the superstructure tends to increase.

2. Direct and Indirect Benefits of Alumina Preheat

Preheating the alumina fed into the bath has the potential to improve the electrolysis process thermal efficiency through many aspects:

a) Reduction in energy consumption to increase the alumina temperature from ambient to process temperature. It can be calculated from Equation (1) where only sensible heat is considered: ΔH is an integration of specific heat C_p over the heat up temperature limits, no phase change is accounted in this process. Approximately 0.56 kWh/kg Al is required.

$$\Delta H \Big|_{25°C}^{960°C} = \int_{25°C}^{960°C} C_p(T)dT \tag{1}$$

b) Dissolution of preheated alumina is easier than cold alumina. When cold alumina is added heat transfer dominates the dissolution process. The cell current efficiency improves if dissolution is improved, as the cell becomes less prone to muck and alumina concentration in the bath becomes more homogeneous. Each 1 % current efficiency gained represents around 0.14 kWh/kg Al for a typical modern cell with 94 % current efficiency (CE) and specific energy consumption (SEC) of 13.2 kWh/kg Al. This is obtained from derivative of the well-known formula for SE: $\Delta SEC = -(\Delta CE/CE)$ x SEC.

c) The alumina dissolution is an endothermic process. The cell superheat must be high enough to be able to provide energy for heating up and dissolving the alumina. The bath superheat can be understood as an energy reservoir used for this task. When feeding preheated alumina, the cell superheat can be lowered and therefore, heat losses through the sidewalls can be decreased. Figure 1 shows the impact of ambient temperature alumina feeding on the local bath temperature. This was measured in a 150 kA point-fed cell at a distance one and a half anode length from the point feeder, which fed 1.4 kg of alumina every 100 s [13].

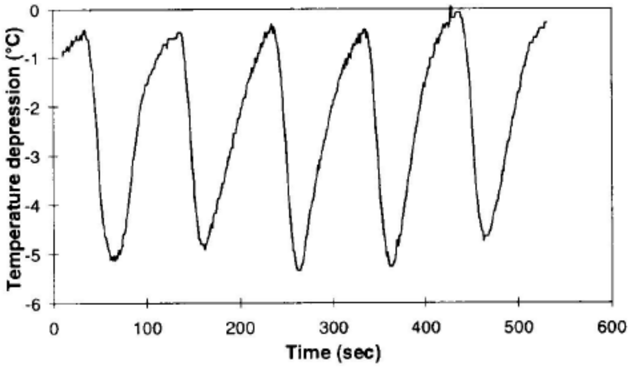

Figure 1. Impact of alumina heat-up and dissolution on local bath temperature [13].

Let us consider a realistic example: a 300 kA cell loses 600 kW through heat dissipation: 50 % from the top, 25 % over the cathode panel and 25 % through side ledge (150 kW). The cell voltage is 4.0 V and energy consumption of 12.5 kWh/kg Al. At the ledge, heat loss Q is proportional to superheat ΔT, ledge area A and heat transfer coefficient h, $Q = hA\Delta T$. If averaged superheat is equal to 10 °C, each degree of superheat lower would mean 15 kW of heat loss saving, which corresponds to 0.16 kWh/kg Al at 94 % current efficiency.

d) The heat exchanger device proposed is accompanied with localized pot suction. This potentially reduces the top heat loss because the under hood space would present lower

- Due to the alumina higher temperature feeding, better alumina dissolution and lower risk of sludge formation is expected;
- Possibility to reduce the electrolyte superheat by up to 50 %;
- Localized exhaust gas reduces the cell under hood temperature, reducing the global top heat losses.

In this paper, the importance of the heat exchanger height has been demonstrated. In new cell designs, the superstructure could be designed to allow more space for the exchanger, further optimizing energy recovery. Model results have also shown that the exchanger diameters present low impact on the heat recovery efficiency.

Despite the potential gains demonstrated in this article, some technical difficulties are expected in the practice. The gas collection cap can be damaged during anode replacement, increasing maintenance costs. The pair of anodes supporting the cap at upstream and at downstream have to be replaced at the same time in order to keep the cap properly aligned.

7. References

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