Impact of Lining Materials Degradation on Reduction Cell Performance

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Abstract

Increase in modern cell amperage and anode size has added a thermochemical stress on sidewall lining materials which could result in accelerated degradation. Variation in cell operating conditions due to routine and non-routine activities will affect degradation rates of side wall lining materials and affect its operating temperature and potentially cell life. In this paper, examples of various impacts of side wall lining material degradation are discussed as part of continuous improvement program. Emirates Global Aluminium (EGA) has adopted advanced cell lining testing to evaluate material suitability for cell operating conditions. The work includes autopsies and side wall inspections. This has contributed to better cell performance.

Keywords: Aluminium reduction cells, Cell lining materials, Cell lining degradation, Cell autopsies.

1. Introduction

Lining design and construction of modern Hall-Héroult reduction cells have undergone continuous development to cope with current operation mode. The cathode, which is lined with carbon materials, refractories and insulation, is designed to operate with optimum performance and achieve maximum cell life. The quality of cell design and construction, and the control of construction materials are critical to achieve required operating conditions. The focus on increasing amperage has increased thermochemical stress on lining materials, and requires better cell operation. Any deviation from the required operating window may result in reduction of cell efficiency, increased energy consumption and lower cell life.

Sidewall lining, which consists of SiC slabs, carbon materials and mortars or glues, significantly contributes to the cell thermal balance and formation of freeze protection. A deterioration of thermal balance may lead to the loss of freeze and expose the side wall lining materials to molten metal or electrolyte, which will destroy the lining and potentially result in sidewall failure. This paper discusses the importance of selection of optimum lining materials, and structured cavity inspections or autopsies to understand cell failure mode and provide required corrective actions. It also describes the testing of these critical materials for further improvement in Hall-Héroult reduction cell design.

2. Silicon Carbide Side Lining

Silicon nitride (Si_3N_4)-bonded silicon carbide (SiC) bricks were introduced as side lining material in the early 1990s. These bricks are made by mixing high purity silicon carbide grains and elementary silicon with an organic binder, then pressed or vibrated to shaped blocks with desired dimensions. These blocks are initially dried at 120 ºC and then put in a furnace in nitrogen atmosphere where the nitridation process takes place at high temperature, maximum of 1400 ºC [1]. It is essential that no oxygen is present during the process to minimise any oxidation reaction [1]. Silicon nitride-bonded SiC bricks are the preferred side-lining material due to their superior resistance to electrolyte attack, high thermal conductivity and high-temperature strength [1-3]. These characteristics are essential to minimise sidewall lining attack by the corrosive electrolyte and to sustain the required thermomechanical strength while operating at high temperature. They also have higher oxidation resistance up to 950 °C, compared to previously used carbon side wall blocks, which could be oxidised at a temperature below 550 ºC. The improved properties of SiC bricks can support smelter higher productivity with amperage increase by using thinner sidewall lining bricks and longer anodes.

EGA has been using SiC bricks in the side wall lining since many years, while testing the bricks from various sources. In one of the tested materials, a noticeably higher degree of degradation of side wall SiC bricks was observed, which resulted in 30-40 % lower cell life in trial pots. Figure 1 shows a highly deteriorated sidewall SiC brick, even though the cell autopsy showed that the sidewall freeze protection against the chemical attack of molten electrolyte was adequate.

Figure 1. Highly reacted sidewall SiC bricks at lower cell life.

Due to the abnormal increase in silicon content in the metal of the test cell, the cell was cut out and autopsied before its target cell life. The test cell operation was thermally stable in terms of bath temperature and superheat, comparable to the rest of the potline. Cryolite resistance test was made on the trial cell SiC slab, shown in Figure 2 as sample A. The showed that the trial cell SiC slab had the highest rate of volume reduction and the lowest cryolite resistance. The chemical analysis of these SiC bricks showed the lowest Si_3N_4 content of 8.31 % and highest residual Si content of 3.9 %. Thus, it had a very low chemical and mechanical resistance to bath

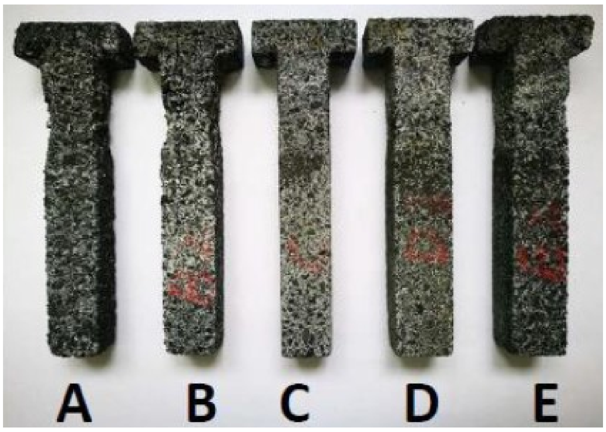

Figure 2. Cryolite resistance test for five different sources of SiC slabs.

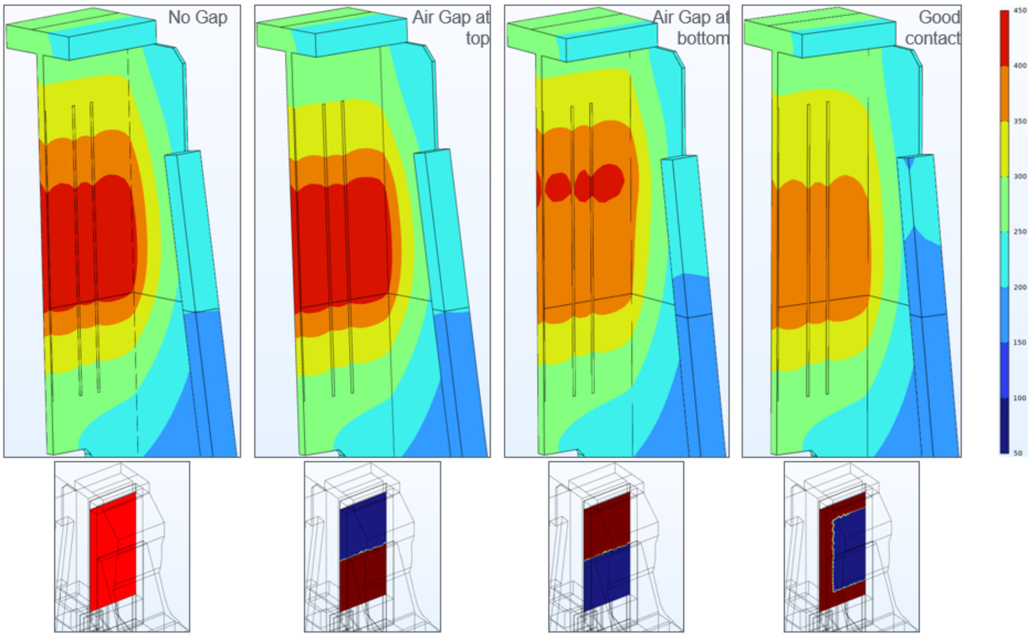

Figure 9. Impact of an air gap on the sidewall shell temperature.

5. Conclusions

Optimum design and selection of Hall-Héroult cell lining material are important for cell performance. Cell operating parameters must adapt to lining material changes with age to achieve long cell life. Selection and testing of lining material should be designed to avoid undesired impact on cell performance and early failures. The study has showed the negative impact of an airgap between the SiC slab and steel shell; it in hinders the formation of protective sidewall ledge which could result in increasing shell temperature and increasing the risk of sidewall failure. Moreover, a thin ledge increases the temperature in the lower sidewall and increases the rate of sodium penetration to the collector bar window and outside the potshell where it attacks bolted copper tabs and increases the bolted joint resistance and cell external resistance. Thus, careful consideration of cell design and material selection is essential for good cell performance.

6. References

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