Impact of copper insert on low amperage aluminium reduction cell

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Abstract

Copper insert in collector bars have been one of the recent research areas for energy reduction in aluminium smelters worldwide. Most of the research on copper inserts has been focused on high amperage cells, which are heat dissipative cells. Use of copper inserts in the collector bars significantly reduces horizontal currents, thus improving cell stability which facilitates energy reduction. However, use of copper inserts also enhances heat loss through collector bars, which could have an adverse impact on thermal balance of low amperage cell, since these cells are designed to be heat conservative in nature. Hence the use of copper insert in low amperage cells requires careful evaluation of thermal balance. In the present study, different designs of copper insert in the collector bar have been analyzed to see their impact on the horizontal current, cathode voltage drop and thermal balance. Simulations have been performed using a validated 3D thermo-electric model. Structural analysis has also been performed for these designs to check the deformation under the thermal stress. Simulation results show that use of copper inserts has potential of energy reduction in low amperage cell, provided that thermal balance of the cell is maintained.

Keywords: Collector bar copper insert; cathode lining; aluminium reduction cell; cell thermal balance.

1 Introduction

Aluminium smelting is an energy intensive process where energy cost is around 40 % of the total cost of aluminium production. Ever increasing energy price and lower London Metal Exchange (LME) price of aluminium have put significant pressure on worldwide smelters to take measures on energy reduction. The typical cell voltage distribution for aluminium reduction cell, given by Haupin [1], is shown in Table 1, which shows the potential areas for reducing the energy consumption.

Table 1. Typical voltage breakup of an electrolytic cell

Cell Component	Voltage (V)
Anode voltage	0.235
Cathode voltage	0.300
External conductors	0.160
Bubble voltage	0.259
Electrolytic bath	1.640
Reaction voltage	1.779
Total pot voltage	**4.373**

Flow of high current through the external busbar generates strong magnetic field in and around the cell. The electric current flowing through the molten metal and electrolyte, interact with the magnetic field and give rise to volumetric forces, known as Lorentz or electromagnetic forces. These forces are responsible for movement of the metal and the bath as well as for deformation of the metal-bath interface, which limits the reduction of inter-electrode gap also known as anode-to-cathode distance (ACD). Cryolite bath is a poor conductor of electricity, which result in maximum voltage drop in the ACD region of the cell. It is desirable to maintain ACD as low as possible while satisfying the heat balance requirement of the cell. The busbar configuration can also be changed to improve magnetic field and achieve better cell stability, however it is capital intensive [2]. Besides optimizing the magnetic field, reduction in the horizontal current is another way to improve the stability of cells and thus reduce ACD [3].

Worldwide many smelters have been evaluating the benefit of using copper inserts in the collector bar. Cu-insert collector bar is known to reduce generation of horizontal currents in the metal region thus improving the cell stability; it also decreases cathode voltage drop [4]. Most of the literature on copper inserts highlights its use in high amperage cells which have high heat loss. Use of copper insert in low amperage cell might adversely affect overall heat balance of low amperage cell, hence need proper evaluation before its use. This paper evaluates the use of copper inserts in low amperage cell with respect to electrical, thermal and structural aspect of the cell by performing simulation studies.

Since copper has much higher electrical conductivity than steel, it alters the electrical resistance path in the cathode assembly. This results in more uniform current distribution in the cathode block and in reduction of horizontal currents in the metal. Copper also reduces cathode voltage drop, and consequently, it reduces the heat generation and thus disturbs the thermal balance of the cell. Since these cells are low heat loss cells due to higher insulation in cell lining, any reduction in ACD enabled by improved cell stability further deteriorates the thermal balance. To compensate this,eventually, extra voltage would be required for stable cell operation. Therefore, the use of copper in the low amperage cell needs to be carefully analyzed before its use and thermal balance needs to adapt to modified conditions by optimizing cell design and process parameters accordingly. The increase in stress in cathode block generated from thermal expansion of copper needs to be evaluated for the structural integrity.
Figure **1** shows two designs of rectangular and cylindrical copper insert in the collector bar. In Case-1 copper insert is rectangular and placed near the top surface of the collector bar, whereas in Case-2 it is cylindrical and placed at the center of the steel collector bar. Along with these two, one unconventional design of copper insert, referred as Case-3 in subsequent sections, has also been analyzed. In each case the volume of copper was kept same and analyzed for electrical, thermal and structural stability of the cell.

Case-1

Case-2

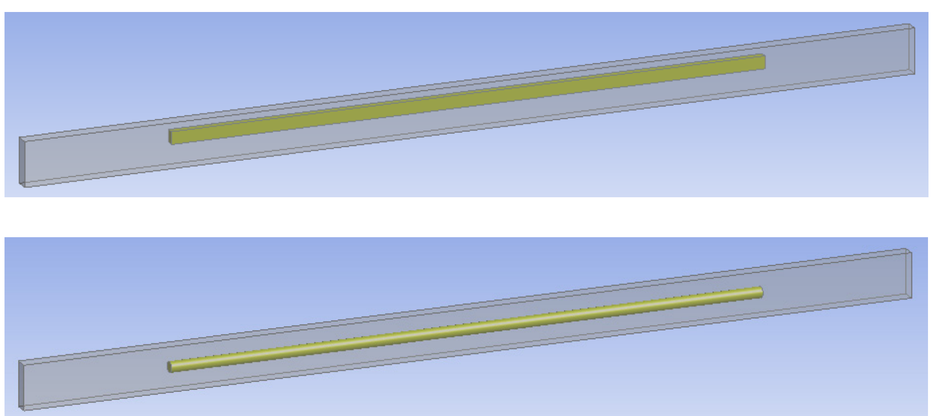

Figure 1. Conventional design of copper insert collector bar.

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