AL25 - Collector Bar Copper Insert Design and Improvements in EGA Technologies

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Abstract

Collector bar copper inserts have been introduced in the last decade in EGA Hall-Héroult reduction cells, with the aim of lowering cathode voltage drop and improving cathode current density distribution. Due to their characteristic difference with steel collector bars, pots with copper inserts require certain refinement in cell design and operation to maximise cell performance and efficiency. Further amperage increase helped to keep pot heat balance. A modelling study showed the possibility of potential improvement in cell magnetohydrodynamic stability and cathode erosion rate in copper insert pots. Autopsy findings of copper insert pots and subsequent design enhancements for further optimisation are also discussed.

Keywords: Hall-Héroult reduction cells, Collector bar copper inserts, Pot autopsy, Pot design, Magnetohydrodynamics.

1. Introduction

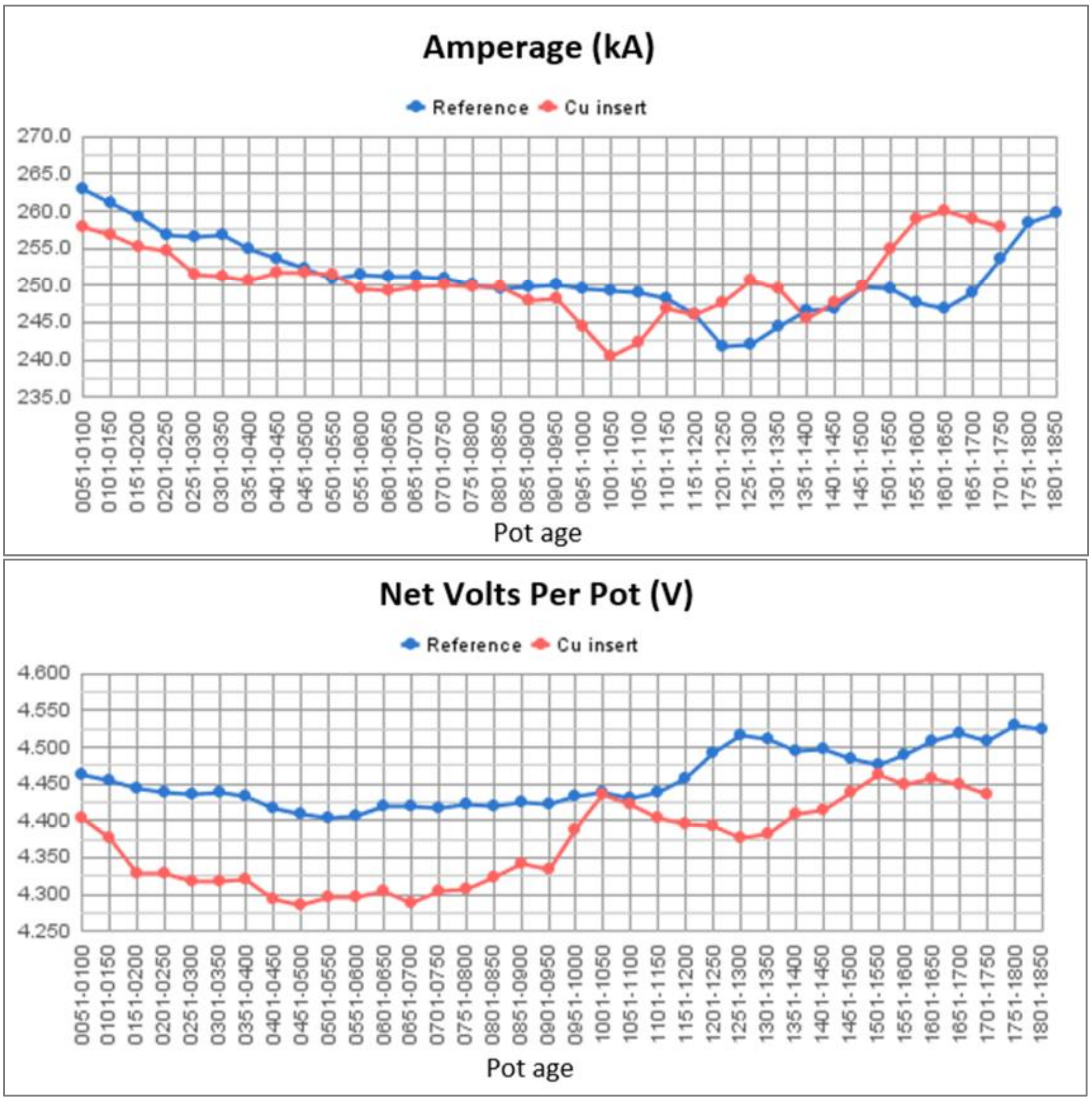
Hall-Héroult reduction cells have undergone continuous design changes, reviews of operating practises, cell control strategy and selection of optimum lining and raw materials aiming to operate at low specific energy, lower carbon foot print and higher cell life. Since, the 1950s, intensive research and development were conducted which has resulted to improve current efficiency from typical 75 % to operate currently at 95 % [1] with corresponding specific energy consumption 13 DC kWh/kg Al now. One of the main drives is to achieve better performance of reduction cells by the development of cathode and collector bar design. Typically, in reduction cells, the current passes from anodes through bath to metal pad where it distributes, due to its high electrical conductivity, according to cathode block and collector bar as well as external busbar resistance [2]. Design enhancement of cathode block and collector bar are interesting because of potential to lower cathode voltage drop [3]. The traditional cathode design uses steel collector bars rodded into carbon blocks with cast iron, although they are poor electrical conductors in comparison to aluminium and copper [4-5]. This is attributed to steel and cast iron superior mechanical strength at high temperatures and high melting temperature.

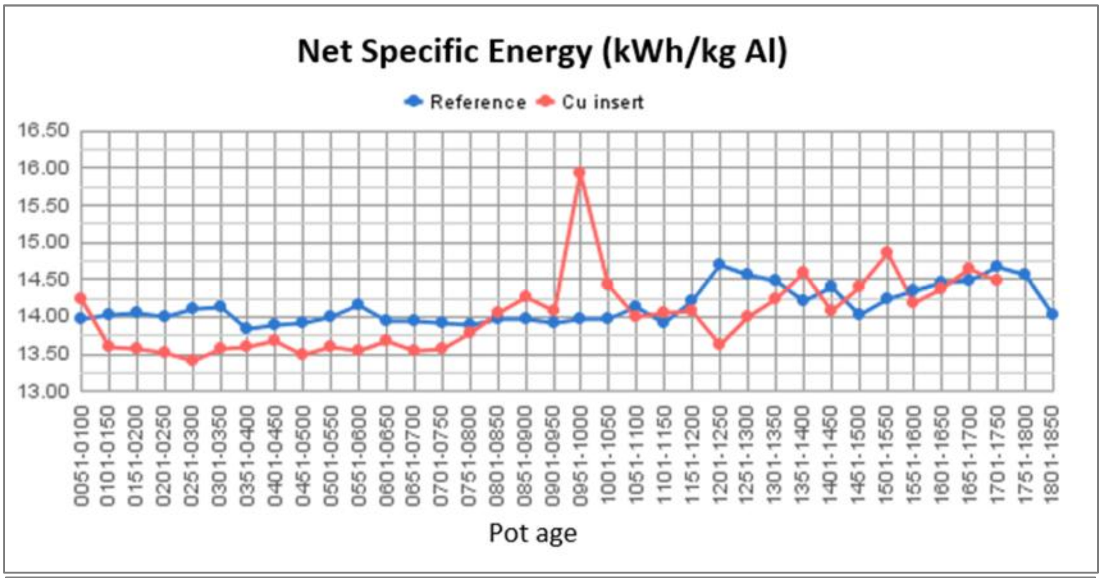
Since reduction cells are designed to have optimum heat dissipation to operate at low specific energy, the introduction of copper insert collector bar design should be carefully studied as copper has higher electrical and thermal conductivity than steel. Copper inserts have been observed to improve current distribution in the cathode and reduce the horizontal current in metal which ultimately improve cell magnetohydrodynamic stability (MHD) [4-6]. This allows the reduction of anode-cathode distance (ACD) which is the main heat generation zone in the cell. At the same time, copper inserts will reduce the overall cathode voltage drop and hence reduce the cathodic heat generation. Lower heat generation and higher heat loss in cells with copper inserts must be balanced with more insulation in cathode lining or with amperage increase.

Emirates Global Aluminium adopted the use of copper insert design collector bars more than a decade ago. Cell autopsies of the first copper inserts pots confirmed the basic cathode design and were used for some design enhancements. This paper discusses the performance of the copper insert cells and illustrates findings of in-situ autopsy measurements.

2. Operational Performance

CD20 was one of the first EGA technology that used copper inserts in steel collector bars. The changeover to Cu inserts started in 2017 and by 2018 all pots were constructed with Cu inserts. In this paper, the performance of copper insert cell design with reference to steel collector bar is discussed. While the data excludes early initial cell performance, it includes around five year of cell performance data since 2018 when copper insert design was implemented. Figure 1 compares some cell operation data between steel collector bar cells and copper insert cells in CD20. A group of 7 pots with Cu insert collector bars is compared against 9 pots with steel collector bars.





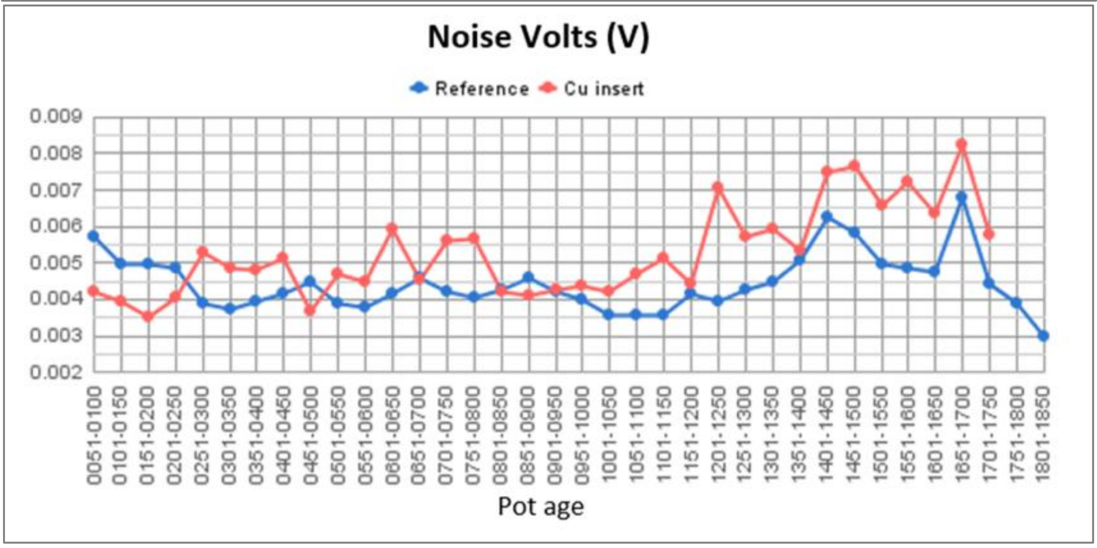


Figure 1. Operational parameter of Cu insert collector bar design versus steel collector bar design.

The net gain in cathode lining drop was sustained since inception at around 60 mV lower voltage drop. The studied technology has experienced amperage modulation where the challenge of satisfying pot thermal balance at lower amperage exists. While operating at amperage of 250-265 kA, copper insert pots has demonstrated good level of cell stability which allowed operating at lower anode cathode distance and reflected on overall net volt saving. However, while amperage was reduced below 250 kA, pots has experienced low superheat operating conditions challenge which has added a stress on cell thermal balance and thus an increase in cell energy input was required to maintain cell heat balance.

Table 1. Summary of average operational data.

Parameter	Cu insert	Reference	Difference
Amperage (kA)	250.9	251.3	-0.5
Nett Volts Per Pot (V)	4.367	4.457	-0.090
Net Specific Energy (kWh/kg Al)	14.02	14.14	-0.12
Noise Volts (V)	0.005	0.004	0.001

3. Autopsy of a Copper Insert Cell

A detailed autopsy plan was conducted for a copper insert cell which was cut out at 976 days. The pot was constructed with impregnated graphitised cathode block, Figure 2.

Figure 2. Autopsy of a copper insert cell with graphitized cathode block, 976 days old.

Cell autopsy was conducted in several stages. The initial stage was to remove metal and bath so cathode surface condition and side wall freeze could be studied. The cell cathode surface was generally flat, though a step reduction in cathode height at certain locations was observed which was undesired and could potentially affect cell life. This could be attributed to a combination of factors such as using a specific type of ramming paste as discussed in [7], possibly breaking off the corners of some blocks (Figures 2 and 3). It was also possible that collector bar currents were non-uniform, but no measurements are available to confirm this.

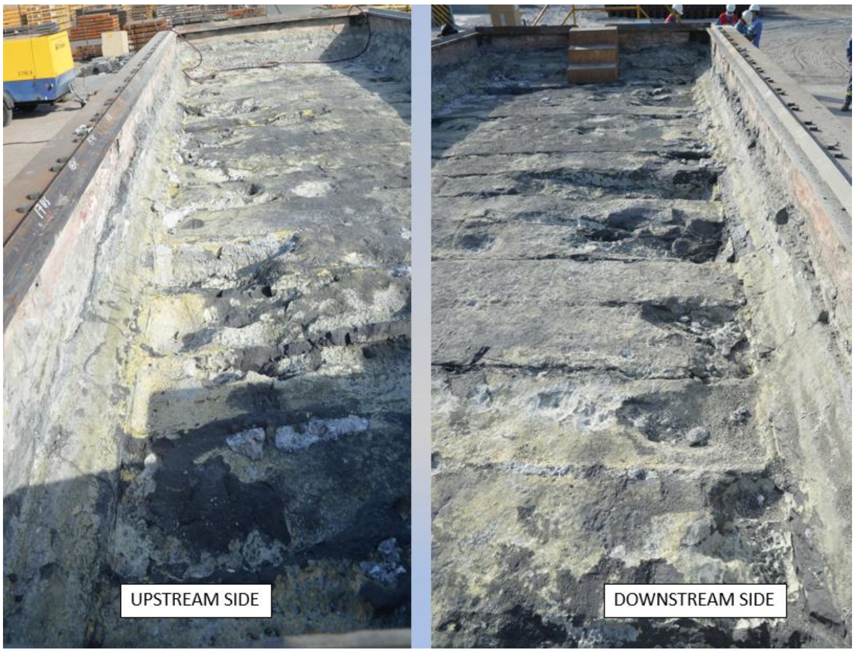


Figure 3. Cathode wear toward the edge.

The observed cathode wear in Figure 3 is considered to be atypical, and it could shorten cell life. Further down the potlining, the collector bars were exposed and on one collector bar some traces of metal were observed, which most likely penetrated through the nearby small seam, Figure 4.

Figure 4. trace of liquid aluminium metal observed on collector bars.

The reaction zone boundary was observed to be at good level, and the condition of sub cathodic lining material was good as shown in Figure 5.

Figure 5. Sub-cathodic lining condition in the copper insert pot.

Similar findings were observed occasionally in some copper insert pots. This led to some improvement of cell lining design.

4. Way Forward

An improved version of copper insert cell design was developed with the objective of improve cathode current distribution, decrease horizontal currents in the metal pad, improve cell stability during amperage modulation and extend cell life. The new design also increased current pick-up near the cell centre channel by reducing the central gap between the collector bars. The cell lining was designed to support pot operation during power modulation and to avoid excessive mechanical stress at cathode edge which resulted in the step break-off of some cathode blocks shown above in Figures 2 and 3.

5. References

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