Experience with Homogeneous Cu Collector Bars Directly Fitted into Cathode Blocks

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Abstract

Cu is increasingly being introduced into collector bar solutions to facilitate amperage increase and energy savings. The most common solution is to fit a copper insert into existing steel collector bars, but this is associated with extra cost as well as challenging recycling at the end of life. Since 2013, Hydro Aluminium has tested a solution where homogeneous Cu bars (cylinders) are fitted directly into the cathode blocks without any cast iron or rodding solution. The solution is very cost efficient with a high potential for recycling of Cu at the end of life. The initial results showed a significantly lower cathode resistance, but a higher increase in cathode resistance with time than for normal steel collector bars. The autopsy results of a preliminary stopped cell showed severe reaction and swelling of the Cu cylinders and a corresponding delamination of the cathode blocks. The degradation of the Cu cylinders and cathode block assembly continued steadily until 1700-2350 days of operation where a dramatic increase of cathode resistance occurred. The rapid increase in cathode resistance led to a rapid increase in temperature followed by melting of the Cu collector cylinders and a dramatic tap-out. The failure mechanisms are discussed.

Keywords: Aluminium electrolysis cells, Copper collector bars, Cathode resistance.

1. Introduction

Cu-inserts in collector bars have more and more replaced the homogeneous steel bars in Hall-Hérault electrolysis cells [1–3]. Cu is an excellent electrical conductor, and the utilization of Cu enables lower cathode voltage drops without increasing the size of the collector bar. Even though Cu is similar in cost to steel when comparing cost/mV of cathode voltage drop (CVD), the Cu-insert assembly imposes a higher cost. In addition, recycling of the Cu at end of life is challenging and a sealing method to fix the collector bar into the cathode block is still needed.

A low-cost solution using homogeneous Cu cylinders directly fitted into a hole in the cathode blocks is described here. The potential benefits of this solution are:

- Low cost (~LME Cu),
- Low CVD combined with high useful amount of carbon in the cathode block,
- Easy and low-cost installation,
- No cast iron rodding,
- Easy to recycle at end of life.

2. Direct Connection

As part of this concept, direct contact between the collector bar cylinder and the cathode block by thermal fitting was utilized. The thermal expansion of Cu, steel and cathode blocks is shown in Figure 1. Steel has a disadvantageous phase transition (with shrinkage) at the operating temperature range which limits its use in direct connection with carbon. Cu has a continuous positive thermal expansion that is higher than the graphitized cathode block and is in addition quite soft at the operating temperature. This makes homogeneous Cu collector bar cylinders a potential candidate for direct thermal fitting.

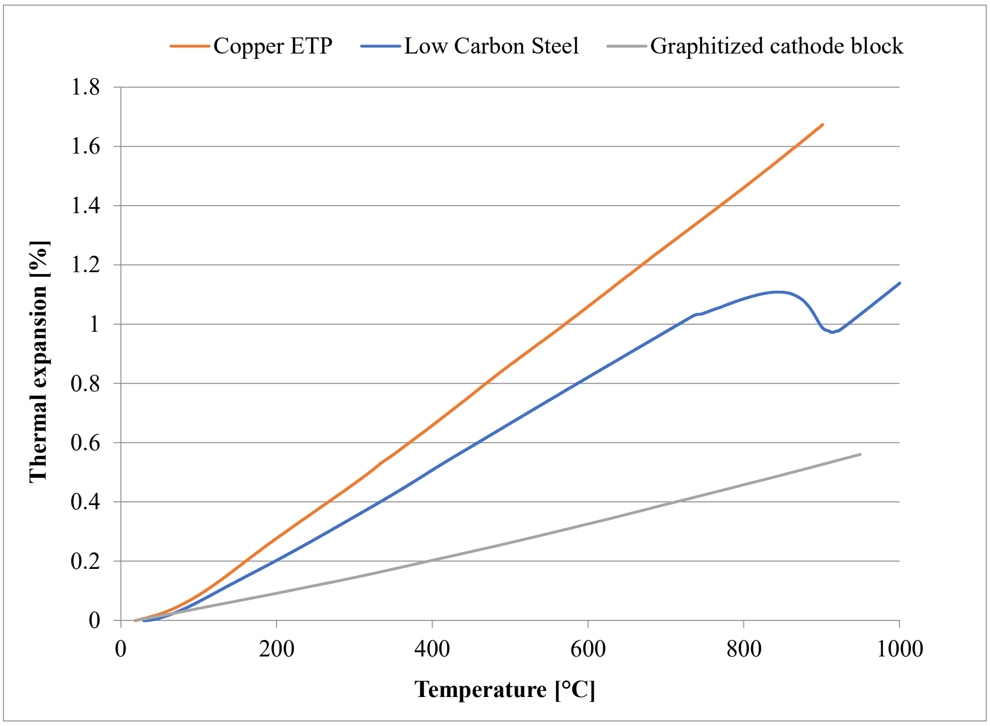

Figure 1. Thermal expansion of low carbon steel, Cu and a typical graphitized cathode block.

A disadvantage of thermal fitting is that a high contact pressure is desired but not so high that the block cracks. This can be achieved with high dimensional precision, but machining to low tolerances is costly. An intermediate solution was chosen where some dimensional deviations in width and straightness could be tolerated.

To check for crack formation during preheating, dummy tests were carried out in a furnace. Pieces of typical cathode blocks were machined according to standard tolerances with holes and Ø 60 mm Cu cylinders, electrolytic tough pitch (ETP) grade, as shown in Figure 2. The assembly was heated to 1000 °C, and the block was visually inspected for cracks after the test. No cracks were observed. To provoke cracks, one Cu cylinder was machined to be slightly larger than the hole in the cathode block sample. The Cu cylinder was then cooled in liquid nitrogen (−195.8 °C) and fitted into the hole. The assembly was heated to 1000 °C and the result is shown in Figure 3. Minor cracks occurred, but crack formation due to thermal expansion was not considered a showstopper for the concept.

Figure 2. Initial crack testing. Left: before testing. Right: after testing, no visible cracks.

for normal steel collector bars. The autopsy results of a preliminary stopped cell showed severe reaction and swelling of the Cu cylinders and a corresponding delamination of the cathode blocks. The degradation of the Cu collector cylinders and cathode block assembly continued steadily until 1700-2350 days of operation until a dramatic increase of cathode resistance occurred. The rapid increase in cathode resistance led to a rapid increase in temperature followed by melting of the Cu cylinders and a dramatic tap-out. The remaining Cu cylinders cells were stopped in a controlled manner.

9. References

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