The Continuous Prebaked Anode Cell – a Pathway to Carbon Capture in Aluminium Production

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Abstract

The routine replacement of spent anodes is the major impediment to achieving process continuity and stability in aluminium electrowinning. It is the root cause of significant process inefficiencies such as complex gas scrubbing systems, and equipment for reprocessing and recycle of the anode butts. These systems add significant capital and operating cost to the process, while adding no value to the metal produced. Further, anode replacement is the major cause of fugitive emissions to the environment, of potentially hazardous interfaces between operator and process, and of contamination of the aluminium product by iron. A continuous anode, where replenishment is achieved without disruption or opening of the process to the atmosphere, offers tremendous advantages on all these dimensions. The continuous anode concept is not new however. As an in-situ, self-baking anode monolith the Soderberg cell won no friends for its environmental credentials but it does provide directions for what is needed to establish a viable, continuous pre-baked anode (CPA) technology. Specifically, the key technical challenges are just two – an effective glue to join prebaked carbon blocks, and a robust and efficient electrical contact and support system that can match the inherent design efficiency of the conventional anode rod and stub assembly. The industry has been surprisingly slow to take these challenges on – but may be forced to in the future should the inert anode not succeed. CPA technology is the enabler for more efficient sealing of the cell, which in turn enables viable carbon capture from a more concentrated cell off-gas. This paper describes work conducted by the authors more than a decade ago to define a viable electrical contact and superstructure design for a CPA cell. The technology awaits proving at an industrial scale for those who see value in this 'diamond in the rough'.

Keywords: Continuous prebaked anode, CPA, carbon capture, electrical contact system.

1. Introduction

The development pathway for reduction cell technology over many decades now has been singularly focused on higher productivity from each cell, this being the key driver of both the investment cost and the operating cost of a smelter. Over the past 50 years we have seen cell current increase approximately four-fold from around 150 kA to 600 kA, with productivity increases of a similar magnitude. There have been important enabling technologies along the way, including automated control of cell resistance and alumina feeding via distributed microcomputers, improved cell designs supported by computer modelling, dry scrubbing and recycle of cell emissions, and increasing levels of sophistication in automation of cell tending and anode processing operations. These improvements have not only underpinned new cell designs, but have also been retrofitted to existing smelters enabling extension of their viable economic life through current creep and improved environmental performance.

There are now indications that the productivity improvement pathway via increasing current, and increasing current density in particular, has run its course. In recent years we see Faraday efficiency, cathode life and net carbon consumption in decline in our modern smelters where current density has been maximised at the expense of other important physical aspects of the process such as electrolyte volume, uniformity of current distribution, and electrode polarisation [1].

At the same time, a new paradigm is emerging to challenge the direction of technology development for the aluminium industry– how to reduce the CO_2 emission from the process (both direct and indirect Scope 2&3 emissions) in the context of a substantial cost that is likely to apply to this emission in future? The Elysis consortium including Alcoa and Rio Tinto are taking on the 'holy grail' challenge of the inert (oxygen-evolving) anode development [2], while Hydro Aluminium are revisiting the chloride electrolysis route [3] which was piloted by Alcoa more than 50 years ago. These are benchmark projects in the industry's quest for a net zero primary aluminium production, but with potentially long and high-risk pathways to commercialisation.

The continuous prebaked anode (CPA) technology offers a different route to net zero CO_2 emission, in addition to its *many* other advantages over conventional prebaked anodes. Specifically, it offers:

- Elimination of the anode butt recycle requirement, reducing the anode baking fuel consumption by 20-25 % (Scope 2 emission).
- Reduction in the net consumption ratio (Scope 1 emission) by around 5% through improvement in anode reactivity as a result of elimination of the butt component.
- Much tighter sealing of the cell from the atmosphere, increasing the off-gas CO_2 concentration to a level where carbon capture becomes economically viable.
- Retrofit capability to existing smelters.

In contrast to the inert anode and chloride electrolysis processes which require significant breakthroughs in materials and /or process engineering, the CPA technology is primarily a challenge for cost-effective mechanical engineering employing conventional materials and processes. It is the 'diamond in the rough' that these authors believe is ready to be polished!
The Urban Dictionary – Diamond in the Rough: "Someone (or something) that has hidden exceptional characteristics and/or future potential, but currently lacks the final touches that would make them (or it) truly stand out from the crowd."

2. The Continuous Prebaked Anode – Concept & Fundamental Challenges

A conceptual comparison of the conventional prebaked anode cell and the CPA cell is shown in Figure 1. In the CPA cell, the consumable anode is replenished without any interruption to the process. As the cell is sealed with off-gas being contained below the upper surface of the anode stack, there is no need to break the seal or open the cell for anode replacement. The new anode is glued to the anode below on which it rests, and the glue is cured when the anode reaches a targeted temperature. The anode stack can be covered for thermal insulation purposes and for protection from oxidation (airburn).

processes. They are challenges for our inventive capability to improve an existing process through the application of sound mechanical engineering, followed by the inevitable development pathway of prototypes to ultimately deliver a viable technology.

VAW demonstrated the CPA concept through nearly 50 years of commercial operation, albeit with significant need for further development of that technology. It is time for another look at this 'diamond in the rough' by those up for the challenge.

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