Development of a New Type of Cathode for Aluminium Electrolysis

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Abstract

Over the past decades, aluminium smelting industry has been increasing significantly its productivity, producing more aluminium per day with lower energy consumption. In this race toward higher the productivity, cathode producers have played a major role with the development of highly conductive cathodes. Indeed, from the older anthracitic cathodes to the newest graphitized cathodes, the electrical resistivity has been divided by 5, leading to lower electrical losses. In recent years, the use of copper in the collector bars has changed the game. With this technology, the heat loss from the cell can be excessive. Consequently, there is a renewed interest for cathodes with intermediate properties, from the older smelters for increasing their productivity and from newer smelters for optimizing their thermal balance. In 2012, it became evident that a new way to produce intermediate properties cathode blocks was needed in order to supply the market. Carbone Savoie has launched an R&D project to adapt to this demand. After a few industrial trials, the targeted electrical resistivity was reached. A complete characterization of the product, including tests at high temperatures, made us confident that a new way was found to produce intermediate properties cathodes. And the cathodes were tested in electrolysis cells.

Keywords: Aluminium electrolysis cells; Cathode; electrical resistivity of cathode blocks; graphitized cathode blocks; high temperature properties of cathode blocks.

1. Introduction

In the aluminium electrolysis cells, the cathode blocks play a major role in the performances of the cell. Indeed, the electrolysis is performed in a molten salts bath at 960 °C and the cathode has to withstand this environment, preventing the leakage of the bath or the molten aluminium. It also has to carry the current. Carbon is an inert material, refractory and conducts current. Thus, it is a good candidate to face these constraints. Until now, only cathodes based on carbon are used industrially at an acceptable cost.

As soon as the cathode fails, the electrolysis cell has to be stopped and relined with new materials. So the resistance of the cathode to the internal environment of the cell is of importance as the cathode wear triggers the end of pot life. Also the thermal and electrical properties of the cathode directly influence the thermal and electrical losses of the electrolysis cell. The design of the electrolysis cell takes into account these properties.

2. Different Cathodes Based on Carbon for the Aluminium Industry

The cathodes based on carbon are made of dry aggregates, usually anthracite, graphite or petroleum coke. These components are sieved, grinded and mixed, following a precise recipe, and bound together with a binder having a high coking value, usually coal tar pitch. High temperature treatment cokefies the binder, making the mix solid and electrically conductive. Final machining is then performed. The process in summarized in the Figure 1.

Depending on the origin of the aggregates and their highest treatment temperature (HTT), very different properties can be achieved. The cathodes are usually sorted into two families:

- The carbon family where the dry aggregates and the binder are heat treated at about 1 000 °C;
- The graphitized family, where after a first baking, the aggregates and the binder are heat treated at about 3 000 °C in graphitization furnaces.

2.1. Carbon cathodes

In the carbon cathodes family, the electrical resistance varies with the graphite / anthracite ratio. The higher the graphite content, the higher the conductivity and also the higher the cost. Anthracitic cathodes have a resistivity of about 45 μΩm; with 100 % graphite, graphitic cathodes resistivity decreases to about 20 μΩm.

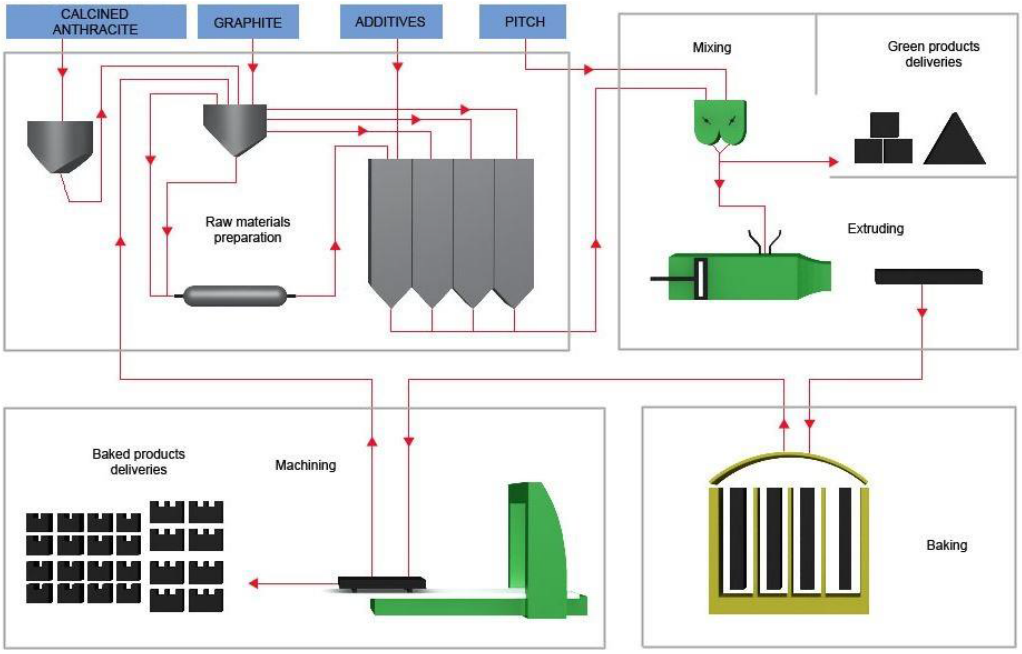

Figure 1. Sketch of the carbon cathode manufacturing.

2.2. Graphitized cathodes

To decrease further the electrical resistivity of the cathodes, another step in the process is needed (see Figure 2). Thanks to Joule effect, the cathodes are heat treated to 3 000 °C. This increases the order in the carbon planes and removes the hetero-atom, leading to a better electrical conductivity. However, this extra-step is energy consuming: between 2 and 8 kWh/kg are needed, depending on the process and the targeted HTT. For cathodes, the graphitization process decreases the resistivity of the product from 35 - 40 μΩm down to 10 μΩm. Lower resistivity of 8 μΩm can be achieved by increasing the HTT. On both cases, the lower cost of the raw materials used, typically petroleum coke, doesn't offset this extra-cost.

7. References

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