Carbon Cathode Block Materials: A History of Advancements

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Abstract

History of carbon cathode materials is a history of upgrading and advancements. There are different philosophies of applications of different grades and compositions of cathode carbon blocks. From the point of view of materials science and processing of carbon cathode materials, there are some questions to be defined.

- Volume effect transformations in course of processing and service. In graphitic blocks, the anthracite in service slowly transforms to carbon with volume decrease and the porosity of blocks should increase; this may open way to enhanced bath flow through the pores.
- From scientific point of view, the degree of graphitization of the synthetic graphite in cathode blocks and its influence on performance is interesting.
- Fracture properties of carbon cathode blocks might be improved, since carbon cathode blocks have elasto-plastic fracture behavior. Yet, it is doubtful that this research will contribute to better models of cathode life prediction.
- Intercalated sodium may move in the lattice of cathode carbon block. The comparison of the velocities of the movement of sodium in the cathode carbon block towards refractory and of the movement of cryolite in the permeable pores of the block are still unknown.
- Clarification for the mechanism of sodium swelling of the carbon cathode block is of scientific interest.
- The problem of the minimization of the cryolite flow through the permeable pores of the carbon cathode blocks is of practical interest.

Keywords: Carbon cathode materials, alumina reduction, volume change of cathode carbon, permeable pores in cathode carbon.

1. The History of Application and Advancement of Carbon Cathode Materials

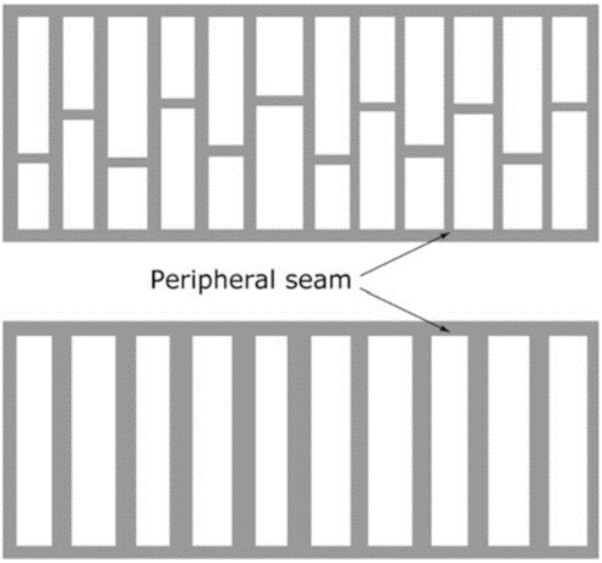
The reduction cell is lined with carbon cathode blocks. The carbon on bottom has two functions:

- To be the vessel of the metallurgical device, where certain levels of the bath and the metal are maintained;
- To conduct electricity which is required for the electrochemical reaction of reduction of aluminium along all the surface of the liquid aluminium.

Permanent improvements of the cathode are taking place from the early beginning of Hall-Héroult process. The material for the first cathode consisted from metallurgical and petroleum coke and pitch, and it was not shaped – it was rammed to the bottom in the form of ramming mix [1]. The first prebaked cathode blocks were installed in the reduction cell in 1920 [1]. The first steel collector bars were installed to prebaked carbon cathode blocks by casting of cast iron in 1927.

Since that time continuous improvement and advancement of the properties and characteristics of carbon cathode materials is taking place. The dimensions of carbon cathode blocks have increased, the shape has changed a little bit, the composition has changed, the properties have improved.

In the earlier days the carbon cathode blocks were split, having the length 1 – 1.2 m and 1.8 – 2.2 m (Figure 1). Nowadays the full-length blocks are up to 3.8 m long and up to 0.7 m wide. The shape of the slot may be different (Figure 2). Now the carbon cathode block is a rather heavy construction, sometimes exceeding one tonne.



(a)

(b)

Figure 1. Scheme of cell with split cathode carbon blocks (a) and with full-length cathode carbon blocks (b).

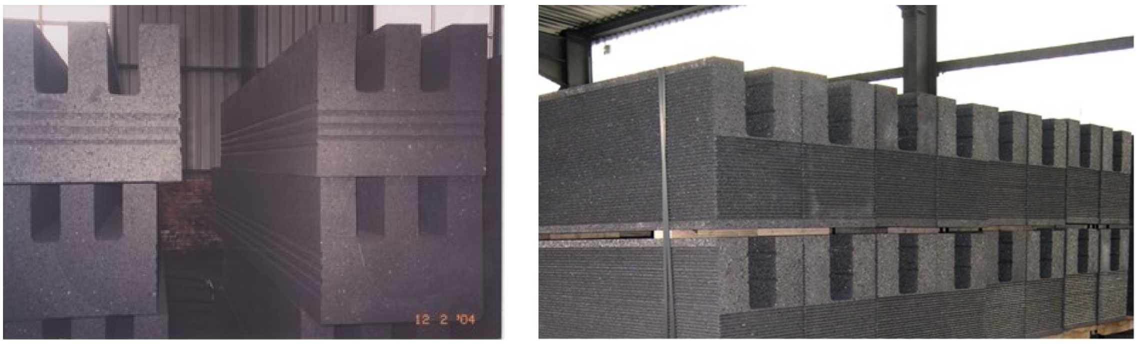


Figure 2. Carbon cathode blocks.

Cathode blocks are shaped by extrusion and by vibro-pressing (vacuum pumping out is sometimes applied to both processes). Extrusion enhances productivity, but vibro-pressing confers the ability to obtain shapes with a lower porosity and higher apparent density. Another advantage of vibro-pressing is the lower amount of pitch (organic binder for shaping) involved. Extrusion requires 20 – 25 % pitch, while vibro-pressing requires 15 – 20 %. During heat treatment, the pitch converts to coke, and in vibro-pressed blocks, there is 6 – 8 % coke, while in extruded blocks, there is 11 – 13 % coke [2]. The porosity of extruded blocks is always 5 – 6 % higher, comparing with vibro-pressed blocks.

In the beginning, carbon cathodes were made from petroleum and metallurgical coke, pitch and anthracite. Anthracite based blocks were used for a relatively long time. There is gas calcined and electrically calcined anthracite. The gas calcination proceeds at 1200 – 1350 °C, the electro calcination proceeds at higher temperature. Electrically calcined anthracite is less homogeneous,

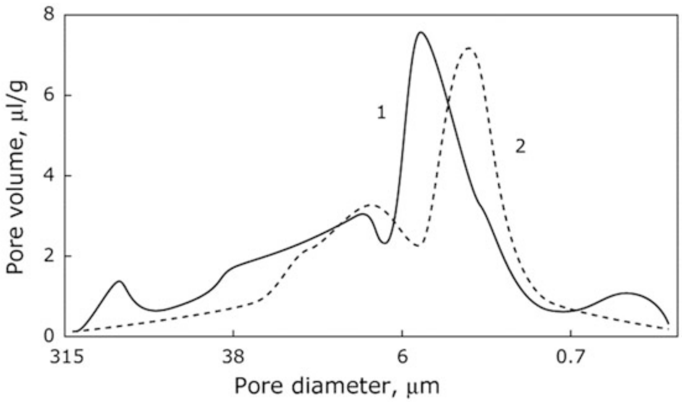


Figure 5. Pore size distribution in different carbon cathode blocks with porosity 16 – 17 % before (1) and after (2) the correction of the grain size composition [2] (the amount of the fine fraction was increased up to 40 %).

Generally speaking, the closed porosity of carbon cathode blocks is 4 – 5 %, the number of dead-end pores is small, and almost all open porosity is a permeable porosity. The rational limitation for the pore size dimension in carbon cathode block may be 25 µm [18]. The question of minimization of pore size dimensions may be solved by optimization of grain size compositions and the use of special additives.

The minimization of the bath flow through the permeable pores of carbon cathode blocks has practical interest. The same may be said about the ramming paste.

3. Conclusions

From the point of view of materials science, there are some questions to be defined in processing of carbon cathode materials for aluminium reduction cells:

- Volume changes in processing and service: In graphitic blocks, the anthracite in service slowly transforms to graphite with volume decrease and the porosity of blocks increases; this may open way to enhanced bath flow through the pores.
- The graphitization of the synthetic graphite in cathode blocks and its influence on performance is still not well understood.
- Fracture mechanics of carbon cathode blocks should be further elaborated, since carbon cathode blocks have elasto-plastic fracture behavior. Yet, it is doubtful that this research will contribute to better models of cathode life prediction.
- The movement of sodium in the cathode carbon block towards refractories and the movement of cryolite in the permeable pores of the block requires further quantitative research.
- Clarification for the mechanism of sodium swelling of the carbon cathode block is of scientific interest.
- The problem of the minimization of the cryolite flow through the permeable pores of the carbon cathode blocks is of practical interest. The question be solved by optimization of grain size compositions and the use of special additives.

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