Production of prebaked anodes for aluminum electrolysis cells: dominant trends, technology, quality

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Production of prebaked anodes for aluminum electrolysis cells: dominant trends, technology, quality

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Abstract. The analysis of the current state of world and domestic production of calcined anodes for aluminum electrolysis cells is carried out. The dominant trends are identified, the basic technology is described, and directions for its improvement are indicated.

1. Introduction

For a long time, the technological strategy of leading aluminum-producing companies is based on the development of electrolysis production using prebaked anodes. This ensures the development and subsequent operation of high-ampere cells working with high technical and economic indicators, improving the sanitary and hygienic working conditions of personnel in electrolysis buildings, and generally improving the environmental safety of aluminum smelters. Currently, this technology produces more than 80% of the world primary aluminum. The implemented technologies of high-ampere electrolysis at electrolytic cells with prebaked anodes with a power of 300-500 kA have proved that a further increase in the efficiency of the process is possible by improving the design and advanced technical solutions using new materials and high-quality raw materials.

The indicators achieved at the leading aluminum enterprises confirm the effectiveness of the chosen direction: the current efficiency reaches 95%, the technological energy consumption is 12500-13000 kW·h/t Al, the anode consumption is 500-510 kg/t Al, aluminum fluoride 15-17 kg/t Al. The use of prebaked anodes significantly reduces emissions of tarry substances, including benzapyrene, and other harmful components from the cell. The possibility of using more airtight shelters with high efficiency, automated alumina feeding systems, which reduce the operating time of cells with open shelters, contributes to the reduction of emissions of harmful substances on high-ampere electrolysis cells.

The main distinguishing features of high-ampere technologies in comparison with medium-sized cells are: use of sand type alumina, fluorine salts, fluorinated alumina and reverse cryolite for feeding the cell through point feeding system; work in a given interval of low alumina concentrations of 2-5% according to technology without anode effects (0.05 pcs/day); low metal level (18-20 cm); high electrolyte level (20-22 cm); the use in the process of only acidic electrolytes with a given interval KO 2.2-2.4; KO corrections according to given algorithms; the ability to work at current densities close to critical values of 0.9-0.95 A/cm^2; high speeds (up to 18-20 cm/s) of the movement of the melt in the electrolysis bath; a new composition of covering materials, providing stabilization of the thermal and material balance; “plant-automatic” technology using multi-function cranes, mechanisms and robotics when servicing with constant scanning monitoring of the technological state of the cell; frame-type

cathode device with additional cooling fins using highly graphitized lock-type cathode blocks and lateral silicon carbide lining with artificial profile overlay.

RUSAL in its medium-term and long-term projects also provides for a continuous increase in aluminum production using prebaked anodes. Sayanogorsk (530 thousand tonnes of Al/year), Khakassky (300 thousand tonnes of Al/year), partially Krasnoyarsk (1024 thousand tonnes of Al/year), Irkutsk (415 thousand tonnes of Al/year) are fully working on this technology. Novokuznetsk (213 thousand tonnes of Al/year) aluminum smelters. Boguchansky aluminum smelter (design capacity of 600 thousand tonnes of Al/year) is under commissioning, Taishet aluminum smelter (design capacity of 750 thousand tonnes of Al/year) is under construction.

2. Condition assessment and forecasts in the production of prebaked anodes

According to [1], in 2019 the global capacity of the global aluminum market may increase to 70 million tonnes with an expected deficit of ~ 1.2 million tonnes. With prevailing in 2015-2017 ratios in the volumes of primary and secondary aluminum production, it makes possible to predict the volume of primary aluminum production at the level of 43.0 million tonnes, and the need for annealed anodes – at the level of 19 million tonnes. The largest plants for the production of prebaked anodes with a production volume of more than 1 million t per year are in China. The leading aluminum-producing companies RIO TINTO ALCAN, ALCOA, RUSAL, EMAL, ALBA are making serious efforts to expand their own production of prebaked anodes.

RUSAL annually produces 3.5 - 3.7 million tonnes of primary aluminum at Russian plants, including using prebaked anodes 1.05 - 1.10 million tonnes. With the development of production capacities of Boguchansky aluminum plant, these figures can reach 1.5 million tonnes, which will require about 810 thousand tonnes per year of prebaked anodes. RUSAL prebaked anode production capacities in Russia include the existing anode production facilities at Sayanogorsk Aluminum Smelter (330 thousand tonnes per year). About 140 thousand tonnes per year are produced by the enterprises of the company ENERGOPROM [2]. The total deficit of prebaked anodes is about 440 thousand tonnes and is covered by imports from China. In this regard, the problem of import substitution is quite acute.

To solve it, RUSAL implements the following projects to increase the production of prebaked anodes:

- at the turn of 2018 – 2019 launch of the production of prebaked anodes at Volgograd aluminum smelter [3] with a production volume of 104 thousand tonnes per year. The project cost is 8 billion rubles with a payback period of 8 years.
- phased construction of the anode production of Taishet aluminum smelter with an output of 870 thousand tonnes per year [4]. Currently, the first stage is being implemented with an output of 217.5 thousand tonnes per year. The commissioning of the production facilities of the first stage is planned in the third quarter of 2019.

3. Multi-chamber furnaces for burning anodes

Anode burning is carried out in multi-chamber furnaces. Moreover, both in domestic and foreign practice, mainly open (anhydrous) furnaces are used, although at a number of enterprises one can find closed (arched) furnaces. Both types of furnaces are undergoing continuous modernization. During the construction of each new production of anodes, a technical and economic assessment of the choice of the first or second type of furnaces is carried out. Nevertheless, over the past 20 years, open furnaces have been given greater preference. A model of an open furnace in a three-dimensional image is shown in figure 1.

The main element of the furnace is firing chambers, directly adjacent to each other through the separation walls. Each chamber consists of 6-8 cassettes located in parallel along the axis of the furnace, and, therefore, is a block of unit cells – cassettes, which are completely identical both in size and in design. The cassette has the shape of a rectangular box, bounded on the sides by the walls of the fire or heating walls, at the ends – by the walls of the inter-chamber partitions, from below – by the surface of the hearth.

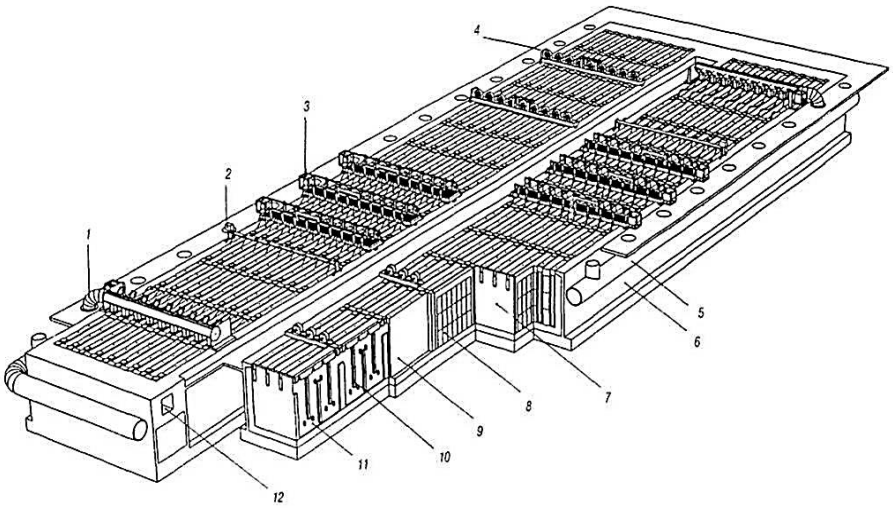

Figure 1. Open anode furnace: 1 – exhauster, 2 – rarefaction control ramp, 3 – fuel bridge, 4 – air cooler, 5 – central smoke bore, 6 – concrete frame, 7 – dividing wall, 8 – anodes, 9 – cassette, 10 – partitions, 11 – heating wall, 12 – flip channel.

To heat the kilns, both gaseous and liquid fuels are used. Fuel is supplied from the central highway to the internal network located around the perimeter of the furnace. The fuel line of the internal workshop network is equipped with individual nozzles opposite each chamber. The nozzles have transitional couplings for connecting to the fuel network of a mobile burner ramp (or bridge), on which the fuel burners are located.

4. The technology of prebaked anodes production

In almost all production of prebaked anodes, the traditional technological scheme as shown in figure 2 is implemented [5-6].

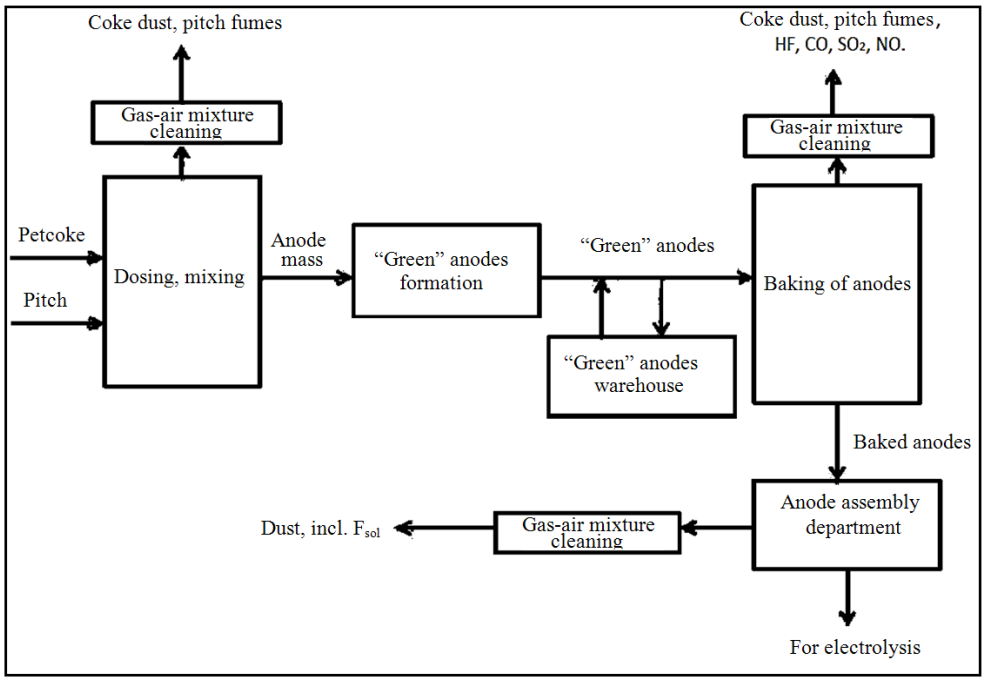

Figure 2. Technological scheme of prebaked anodes production.

In multi-chamber furnaces, prebaked anodes are at rest, i.e. motionless, and the zones of preheating, firing and cooling periodically move from chamber to chamber of the furnace. Due to this, the anodes of each chamber within one cycle go through all stages of firing and cooling in accordance with the technically sound schedule. The entire heat engineering cycle, including the preheating, forced heating and cooling zones, as well as the preparatory cycle chambers (loading, unloading) is called “fire”. With 72 cameras, the furnace operates on 4 “fires”. “Fire” moves through the furnace “at a speed” of 24-28 hours per camera.

After firing and cooling, the anodes are unloaded from the chamber using a universal bridge crane onto a conveyor with a pushing rod. Unloading one cartridge lasts in average 60 minutes. After unloading, the anodes are transported to the treatment station, where they are cleaned of coked dust with scraper knives and blown with air.

After the cleaning station, the anodes are fed to the transmission device, which lowers the anodes from the furnace site to the roller conveyor, divided into three sections. The middle section of the roller conveyor serves to stop the anodes for the purpose of visual inspection and, if necessary, manual purification. Defective prebaked anodes through the rotary table are sent to the conveyor and then to the crushing site. Useful prebaked anodes are transported by conveyors with a pushing rod to the loading area on an overhead conveyor with pallets and are transported to a warehouse. Prebaked anodes are shown in figure 3.

Figure 3. Prebaked anodes as a part of the anode device in the aluminum cell.

RUSAL enterprises produce anode blocks of various sizes and purposes. For low-power cells, type A blocks are produced in size 550x400, height 510 mm. On modern cells, anode blocks of types B and C are widely used (figure 4). The technical requirements for prebaked anode blocks were developed by the Swiss company R&D Carbon Ltd. The most significant of them are given in table 1 [7, 8].

Table 1. Quality indicators of the anode blocks.

Quality indicators	Typical value
Density:	
- volumetric, kg/dm^3,	1.53-1.58
- true, kg/dm^3,	2.05-2.08
Specific electric resistance, μOhm·m	52-60
Strength:	
- bending, MPa,	8.0-12.0
- compressive, MPa.	32.0-48.0
Thermal conductivity, W/m·K	3.0-4.5

CO_2 reactivity:	
- scaling, %,	4.0-8.0
- oxidation,%.	10.0-20.0
Ash content, %.	0.2-0.5
Impurities content, ppm:	
- S	1.2-2.4
-Si	100-300
-Fe	100-500
-V	80-260
-Na	200-600

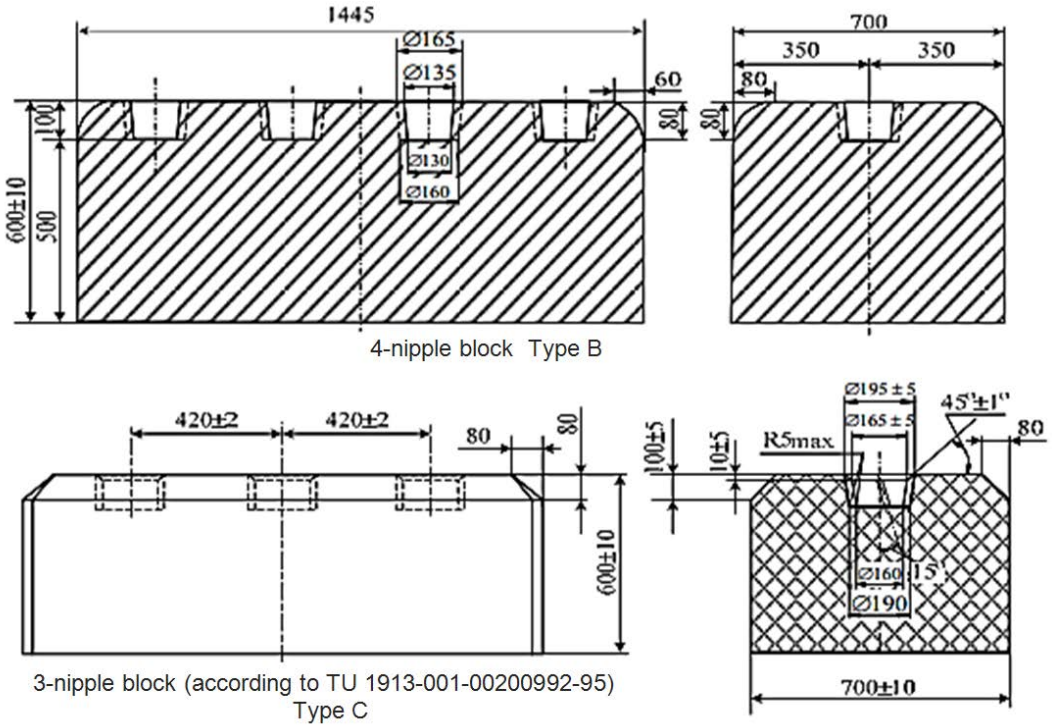

Figure 4. Anode blocks of type B and C.

5. Conclusion

The state of world and domestic production of prebaked anodes for aluminum cells was assessed. Based on the analysis of scientific and technical literature, the main trend of modern electrolysis production was confirmed – the development and operation of high-ampere electrolytic cells with prebaked anodes, which have increased environmental safety. The global demand for prebaked anodes is estimated at 19 million tonnes, RUSAL – 0.8 million tonnes. Moreover, the total shortage of prebaked anodes in UC RUSAL is 0.44 million tonnes and is covered by imports from China. In 2019, RUSAL plans to commission new capacities – 0.1 million tonnes at Volgograd and 0.22 million tonnes at Taishet aluminum smelters. The phased development of the anode production in the conditions of Taishet aluminum plant will ensure the production of 1.3 million tonnes of prebaked anodes for RUSAL.

It was confirmed that the leading aluminum-producing companies – RIO TINTO ALCAN, ALCOA, RUSAL, EMAL, ALBA are making serious efforts to expand their own production of prebaked anodes using mainly open-type multi-chamber furnaces, providing 4-stage firing with high-quality anodes production at minimal energy costs. The expansion of the production of prebaked anodes is accompanied by the improvement of furnace designs, firing technology, replacement of fuel

(fuel oil with natural gas), with the formation of protective coatings on the anodes, a change in their geometry (the presence of gas channels), etc. The use of new technological schemes for the treatment of exhaust gases significantly increases the environmental safety of anode production.

References

[1] Chernavina D A, Chernavin E A, Faller A V and Zdanovich M U 2018 *Young Scientist* **17** 206-210
[2] Prebaked anodes ENERGOPROM https://www.epmgroup.ru/ru/
[3] Pleshakov V *Volgograd Aluminum Plant is Ready to Launch the Production of Anodes* https://vpravda.ru/ekonomika/alyuminievyy-zavod-volgograda-gotov-zapuskat-proizvodstvo-anodov-58439/
[4] *Taishet Aluminum Smelter. Construction* http://visinform.ru/?action=view&id=4345&module=articles&rubric=20
[5] Nikiforov V P, Palchikov A I and Matveev Yu A 1982 *Production of Prebaked Anodes vol III book 3* (Leningrad) p 782
[6] Yanko E A 2001 *Anodes of Alumina Reduction Cells* (Moscow: Rydy I Metally) p 672
[7] *Aluminum Market Review. Aluminum Association* http://www.aluminas.ru /upload/iblock/4ab/2016 – aluminium-market-reviev.pdf-2016/
[8] Galevsky G V, Mintsis M I and Sirazutdinov G A 2009 *Aluminum Metallurgy. Reference Book on Technology and Equipment* (Novokuznetsk) p 251