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To cite this article: M I Mintsis and G V Galevsky 2018 *IOP Conf. Ser.: Mater. Sci. Eng.* **411** 012048

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Modernization of the cathode assembly of aluminum electrolysis cells with Soderberg anode during the AAFS introduction

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Abstract. The state of the cathode assembly on Soderbergh electrolysis cells is analyzed, and measures for its improvement are proposed.

1. Introduction

Aluminum electrolysis with Soderberg anodes now constitute about 70% of all types of electrolysis cells in Russian plants. The dominant part of these cells was developed in the 50's of the last century and was designed for the technology in which the electrolyte was fed by alumina periodically (every 3 or 4 hours). In these conditions the electrolyte mass should absorb as much alumina as it is necessary for the cell to work for 3 to 4 hours. The labour costs for the delivery of alumina to the cell and its immersion into the electrolyte melt account for 40% of the total labour of technological personnel.

At the moment the work on the introduction of the automated alumina feeding system (AAFS) at Krasnoyarsk Aluminum Plant has been completed, and in a number of plants the work on the introduction of AAFSs is still being carried out. The introduction of AAFSs not only increases the productivity of technological personnel, but also completely changes the electrolysis technology – the frequency of anode effects is sharply reduced, the concentration of alumina in the electrolyte and the magnitude of the inter-pole distance, etc. are stabilized. However, this technology change is not accompanied by a corresponding change in the cell design.

With the introduction of AAFSs the duration of alumina supply to the melt is sharply reduced – from 3 to 4 hours to several minutes. In these conditions the required volume of electrolyte is reduced.

Unfortunately, in the educational and technical literature there is no method for determining the volume of electrolyte in the shaft, which complicates the justification of the minimum value of the technically necessary volume of electrolyte in the conditions of its feeding with alumina by AAFSs.

2. Calculation of the electrolyte volume in the cathode assembly

Below is a procedure for determining the volume of electrolyte in the cathode assembly, and its scheme, used to calculate the mass of electrolyte in the cathode assembly, is shown in figure 1.

The volume of electrolyte V_e (dm³) in the cathode assembly is determined by the expression:

$$V_e = (S_m \cdot H_e) - S_a \cdot (H_e - L_{ipd}), \quad (1)$$

where S_m – the melt surface, dm²;

H_e – the height of the electrolyte column above the metal, dm;



S_a – the anode area, dm^2 ;

L_{ipd} – the inter-pole distance, dm.

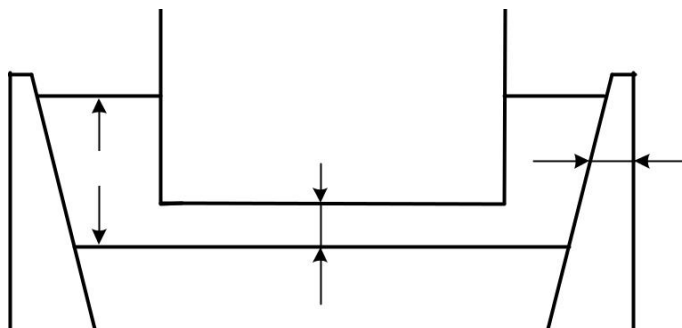


Figure 1. Calculation scheme.

The surface of the melt S_m , taking into account the average thickness of the side accretions n (dm), is determined by the following expression:

$$S_m = (L_{ca} - 2sa) \cdot (B_{ca} - 2sa), \quad (2)$$

where L_{ca} and B_{ca} – the length and width of the cathode assembly, dm.

The anode area S_a (dm^2) is defined by the expression:

for Soderbergh electrolysis cells
$$S_a = L_a \cdot B_a, \quad (3)$$

and for BA cells
$$S_a = n_b \cdot S_b = n_b \cdot L_b \cdot B_b, \quad (4)$$

where L_a , B_a – the length and width of the anode, respectively, dm;

n_b – number of anode blocks, pcs;

S_b – the area of the anode block dm^2 ;

L_b and B_b – the length and width of the anode block, respectively, dm.

The electrolyte mass M_e (kg) in the cathode assembly is equal to the product of its volume V_e (dm^3) by the density of the electrolyte d_e , which is about 2.08 kg/dm^3 :

$$M_e = V_e \cdot d_e. \quad (5)$$

For calculations it is convenient to use the concept of the electrolyte specific mass, m_e (kg/kA), which is equal to the ratio of the electrolyte mass, M_e , to the current I_c (kA):

$$m_e = \frac{M_e}{I_c}. \quad (6)$$

3. Results and discussion

To determine the required amount of electrolyte in the cathode assembly, we determine the demand for alumina q_{al} (kg/kAh) per 1 kA for one hour. To do this, we determine the specific capacity of the cell q_a (kg/ kA·h) for a time $t = 1 \text{ h}$ at a current strength $I_c = 1 \text{ kA}$ and an output current $\eta = 0.9$:

$$q_a = 0.3356 \cdot I_c \cdot t \cdot \eta = 0.3356 \cdot 1 \cdot 1 \cdot 0.9 = 0.30,$$

and the specific demand for alumina q_{al} for the production of aluminum q_a will be

$$q_{al} = 1.889 \cdot q_a = 1.889 \cdot 0.30 = 0.567 \text{ kg/kA} \cdot \text{h}.$$

The solubility of alumina in the electrolyte depends on many factors, which are discussed in detail in [1]. During in-line treatment of the crust, the maximum value of the alumina concentration in the electrolyte $C_{\max}$ occurs some time after it is fed into the electrolyte. In the process of electrolysis not all alumina dissolved in the electrolyte is consumed, since an anodic effect occurs when a certain critical value of its concentration C_{cr} is reached. In order to avoid the occurrence of anodic effect, it is necessary to introduce the next portion of alumina into the electrolyte at the moment when its concentration value will be the minimum allowable $C_{\min}$, but above the value C_{cr} . Thus, the amount of alumina that can be produced from the electrolyte depends on the difference in values:

$$\Delta C = C_{\max} - C_{\min} \quad (7)$$

Depending on the quality of alumina, electrolyte parameters, anode current density, the value of $C_{\max}$ with modern technology is about 6.0% [1], and $C_{\min}$ – about 2.5%. Then the value of ΔC is about 3.5% of the electrolyte mass.

The specific mass of the electrolyte q_e required to dissolve q_{al} of alumina in the agreed conditions will be:

$$q_e = \frac{q_{al}}{\Delta C} = \frac{0.567}{0.035} = 16.2 \text{ kg/kA} \cdot \text{h}. \quad (8)$$

In the case of 8-fold treatment of the crust, alumina is fed into the melt approximately every 3 hours. Consequently, the required specific gravity of the electrolyte must be $16.2 \cdot 3 = 48.6 \text{ kg/kA} \cdot \text{h}$.

When the electrolysis cell is equipped with the AAFS system, the process is carried out with the alumina concentration about 2.5% in the electrolyte, since the electrolyte electrical resistance is minimal. Another portion of alumina is fed into the melt with a periodicity of several minutes. That is why the required amount of electrolyte should be much smaller.

For comparison we calculate the specific volume of electrolyte for the most widely used in the plants of Russia Soderberg cell of S8BM type and the modern electrolysis with burned anodes of RA-300 type installed in KhAZ, the parameters of which are presented in the table 1.

We calculate the volume V_e , its mass M_e and the specific mass m_e of the electrolyte for each type of cell.

Assuming the height of the electrolyte column H_e is 1.8 dm, the inter-pole distance $L_{ipd} = 0.5$ dm, and the thickness of side accretions in the electrolyte zone – 1.0 dm, we get:

- for electrolysis cell S8BM:

$$V_e = (S'_m \cdot H_e) - S_a \cdot (H_e - L_{ipd}) = V_e = (3606.4 \cdot 1.8) - 2394 \cdot (1.8 - 0.5) = 3379.3 \text{ dm}^3;$$

$$M_e = V_e \cdot d_e = 3379.3 \cdot 2.08 = 7029 \text{ kg}; \quad m_e = \frac{M_e}{I_c} = \frac{7029}{172} = 40.86 \text{ kg/kA}.$$

- for electrolysis RA-300:

$$V_e = (S'_m \cdot H_e) - S_a \cdot (H_e - L_{ipd}) = V_e = (5037.4 \cdot 1.8) - 3641 \cdot (1.8 - 0.5) = 4333.5 \text{ dm}^3;$$

$$M_e = V_e \cdot d_e = 4333.5 \cdot 2.08 = 9013.6 \text{ kg}; \quad m_e = \frac{M_e}{I_c} = \frac{9013.6}{320} = 28.16 \text{ kg/kA}.$$

Table 1. Parameters of electrolysis cell S8BM and RA-300.

Parameter	Measurement unit	S8BM	RA-300
Anode - length	dm	84	14.45

- width	dm	28.5	7
- number of blocks	pcs	1	36
- area	dm ²	2394	3641.4
- current density	A/cm ²	0.722	0.878
Bottom			
- length	dm	94	143.5
- width	dm	41.2	37.6
- area	dm ²	3872.8	5395.6
- current density	A/cm ²	0.446	0.593
Calculated parameters:			
- volume	dm ³	3397.3	4333.5
- macca weight	kg	7029	9013.6
- specific weight	kg/kA	40.86	28.16

Thus, at the electrolysis cell RA-300 equipped with an APG system, at a distance between the anode mass and the cathode assembly side of 350 mm, the specific weight of the electrolyte is 28.16 kg/kA, which is 1.45 times less than in the cell of the S8BM type.

In modern foreign cells with BA, the distance between the anode massif and the side of the cathode assembly is 250 mm, and the specific volume of the electrolyte does not exceed 25 kg/kA, which is 1.63 times less than in the S8BM cells.

Reducing the width of the cathode assembly will lead to a significant increase in the cathodic current density, by which is meant the ratio of the current to the mine area. Currently, in the electrolysis cells with burned anodes, the anode current density, according to Gibson Crest Pty Ltd, is 0.85-0.9 A / cm². In this case, the ratio of the area of the anode to the area of the bottom is recommended to be within 0.85 - 0.9, that is, the cathode current density should be at least 0.72-0.80 A/cm².

The anodic current density at the Soderberg anodes is unattainable in the anode cells of Soderberg anodes. At the 173 kA electrolysis cells, the anode current density has reached 0.725 A/cm², but the cathode current density is only 0.447 A/cm². Such a low cathode current density leads to a decrease in the current output, subcooling of the bottom, the formation of floorboards under the anode, and increases the material consumption of the cathode device.

Apparently, the effective anodic current density without upgrading the Soderberg BT anodes will not exceed 0.75 A/cm², but it is advisable to increase the cathode current density, which will certainly reduce the metal losses due to the reverse reactions, or, in other words, increase the current output. There is reason to believe that the life of a narrow cathode device will increase.

4. Conclusion

The obtained results show that there is a possibility of reducing the melt volumes in the cathode assembly of the bath by reducing the distance between the anode and the side of the cathode assembly. This will reduce the material consumption of the cathode assembly by approximately 20 % and will adequately reduce the costs for general repairs. In this case, the surface area of the electrolyte will also decrease by approximately 20%, which will positively affect the emission of toxic gases into the atmosphere of the casing.

References

- [1] Isayeva L A and Polyakov P V 2000 *Alumina in the Production of Aluminum by Electrolysis* (Krasnoturinsk: Publishing house "BAZ") p 198