CALCULATION METHOD FOR THE REFERENCE RESISTANCE IN VIEW OF OPTIMIZING THE HEATING STABILITY OF AN ALUMINUM ELECTROLYSIS POT

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Prezentul studiu, a permis identificarea unei relații de corelare cu un coeficient ridicat de determinare $R^2 = 0.91$, între evoluția gradului de instabilitate în funcționarea cuvelor şi principalii parametrii tehnologici medii, realizați pe o anumită perioadă de funcționare, respectiv căderea catodică medie, tensiunea medie realizată, media efectelor anodice, vârstă cuvă.

Aceste relații creează posibilitatea recalculării individual pe fiecare cuvă în regim automat, la intervale prestabilite de 10 - 20 zile, a rezistenței de referință, care să asigure o bună stabilitate termică în funcționare cât şi un grad de instabilitate cât mai redus.

This study has allowed the identification of a correlation, with a high determination coefficient $R^2 = 0.91$, between the evolution of the level of instability in pot operation and main average process parameters achieved over a certain operating period, namely the average cathode drop, the actual average voltage, the average number of anode effects, the pot age.

These relations create the possibility to perform individual recalculation for each pot, in automatic mode at 10 - 20 day preset intervals, of the reference resistance that would ensure a good operating thermal stability as well as a level of instability as reduced as possible.

Keywords: reference resistance, working voltage, overheating tendencies

1. Introduction

Optimization of a heating stability of an electrolysis pot is mainly determined by correct determination of the reference resistance value at which an electrolysis pot should be operating (working voltage). The use of a reference resistance lower than the optimum operating value leads over time to periodic occurrence of instability tendencies, which determine the use of additional voltages (RC) in order to bring the pot back to a normal operating condition.

Imposing a reference resistance higher than the optimum operating one could over the time lead to overheating tendencies, which determine a higher AlF_3

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consumption and a reduction of pot efficiency as compared to the rest of the potroom [1].

In the case of the pots having reference resistance lower than the optimum operating one, the occurrence of instability tendency mainly leads to the following situations:

- use of additional voltage (RC), established by the process operator depending on the level of instability 50 - 200 mV, which leads to an increase of the pot's actual average voltage;
- the pot's efficiency can be significantly reduced; during a strong instability process, the efficiency can drop by 10-20% below a normal pot operating efficiency.

Consequently, in the case of a pot undergoing significant instability for 2-3 hours, during which it can be admitted to have an efficiency of maximum 80%, it will, during that particular day, entail an average efficiency of at least 2 percent lower than the current pot value, as well as an average voltage approximately 30 - 40 mV higher than the current average values. Practically, during that particular day, the pot has a specific power consumption by approximately 200 ÷ 400 kWh/t higher than the average value of the potroom [2].

2. Principle of the method:

The influence of the level of instability on the process parameters was estimated from pot balance data and from the efficiencies achieved during that particular period:

- the pots having a high level of instability require during those days to use doses of alumina 15-20% lower than the current average and implicitly a proportionally lower efficiency (partly due to feeding additional Al_2O_3 caused by the frequent movements of the anode frame to adjust the operating voltage);
- on the highly unstable pots the alumina feeding program frequently stops the anode effect calculation program (it no longer operates with the 3 alumina feeding phases, namely overfeeding, quick feeding and underfeeding) and switches to a theoretical feeding which corresponds to alumina feeding rates of average pot consumption levels.

Experimentally, during the high instability periods, feeding rates 30-40% higher than the normal pot consumption (theoretical feeding) have been used, and it was noticed that, 3-4 hours of operation later, such underfeeding level did not cause the pot to have an anode effect [3-4].

Practically, if we admit that the pot efficiency does not change significantly during the instability period, in maximum 1.5 hours the pot should have indicated an anode effect due to the sudden decrease of the Al_2O_3 concentration in the electrolyte (caused by underfeeding by approx. 40% as compared to the normal consumption of a pot during this instability period).

This proves that the efficiency of a pot undergoes major drops during the high instability period and that the use of theoretical feeding rates, as calculated during the pot's normal operating periods, can lead both to the increase of Al_2O_3 content in the electrolyte over the normal limits as well as to the potential occurrence of additional alumina deposits on the pots' cathode (due to overfeeding the electrolyte and decreasing the solubility of the dosed alumina).

3. Results and Discussion:

Considering the importance of establishing a calculation method for the optimum reference resistance of an electrolysis pot, we are presenting below a study resulted from processing the technological parameters in a test section of 15 pots during a 12 month timeframe.

Theoretically, for an electrolysis potline we could use a reference resistance under the following conditions:

- pots should be built according to a sole construction project;
- the materials used for pot construction should have comparable physical and mechanical features (bricks, cathodes, SiC slabs, ramming paste).

Depending on the pots' age, when cathode drop varies according to their age, the reference resistance additional correction program is automatically done further to the individual cathode measurements performed at 4 day intervals.

In reality, for pot construction there are used several types of cathodes that have different thermal conductivity coefficients, which entails that two pots having the same cathode have different operating voltages.

A similar case occurs for the SiC slabs or pot lining bricks which have different thermal conductivity coefficients.

Also, an advanced erosion of the ramming fillet or even of the cathode can lead to the increase of the heat transfer towards the outside of the pot, and, consequently, to the pot's tendency to operate in a colder mode.

In such case, the use of a sole reference resistance value does not meet the thermal balance needs of all pots operating in a potline.

To perform an assessment of the main factors influencing the pot reference resistance we have performed the processing of a series of average data resulted from a group of 15 test pots, which are presented below.

From correlating the average voltages achieved at each pot with the average value of the cathode drop, the correlation result is 70% (Fig. 1 and 2).

$$\mathbf{U}_{\mathbf{aver./pot}} = 69.074 * \text{cathode voltage} + 3925.4 \qquad (1)$$

Cathode voltage - actual average value of cathode drop per 30 days

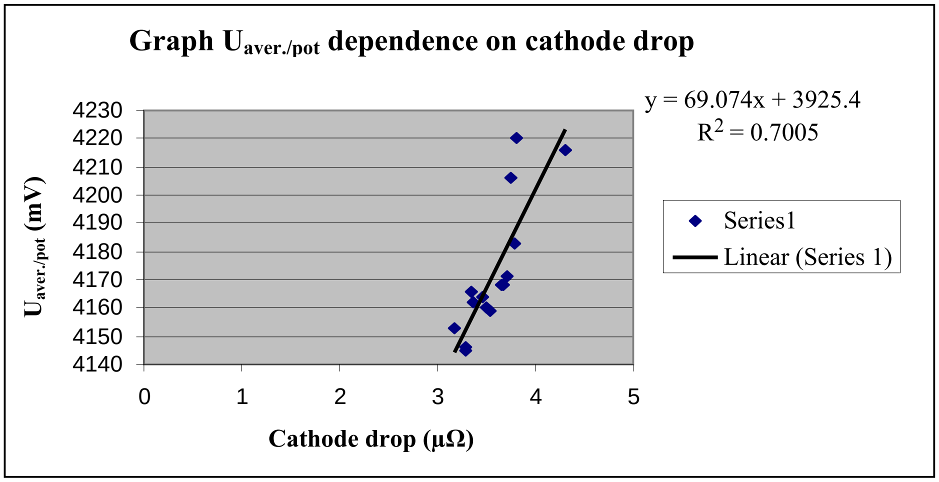

Fig.1 $U_{aver./pot}$ dependence on cathode drop

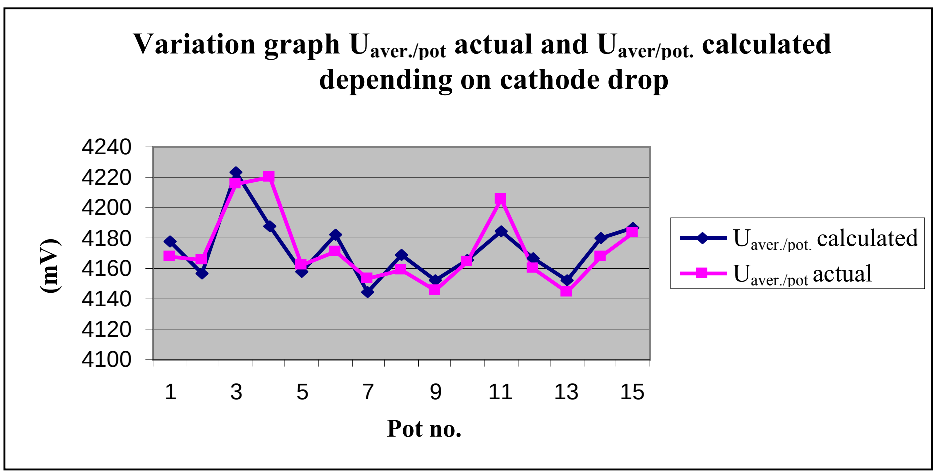

Fig. 2. Variation graph $U_{aver./pot}$ actual and $U_{aver./pot}$ calculated depending on cathode drop

Further, the LINEST function is used to calculate $U_{aver/pot}$ calculated depending both on the cathode drop and on the rest of the parameters that can influence the pot $U_{aver.}$ and consequently a status of the pot thermal condition.

Fig. 3 and 4 present the evolution of $U_{aver/pot}$ actual and $U_{aver/pot}$ calculated, depending on the cathode drop and on the average number of anode effects (A.E.).

The obtained equation has a higher degree of correlation as compared to the calculation equation (1) reaching a correlation level of 80%, against the 70 % of the calculation equation # 1.

$U_{aver./pot}$ calculated = 3881.54 + 108.73*Aver.AE + 79.32*Cathode drop aver. (2)

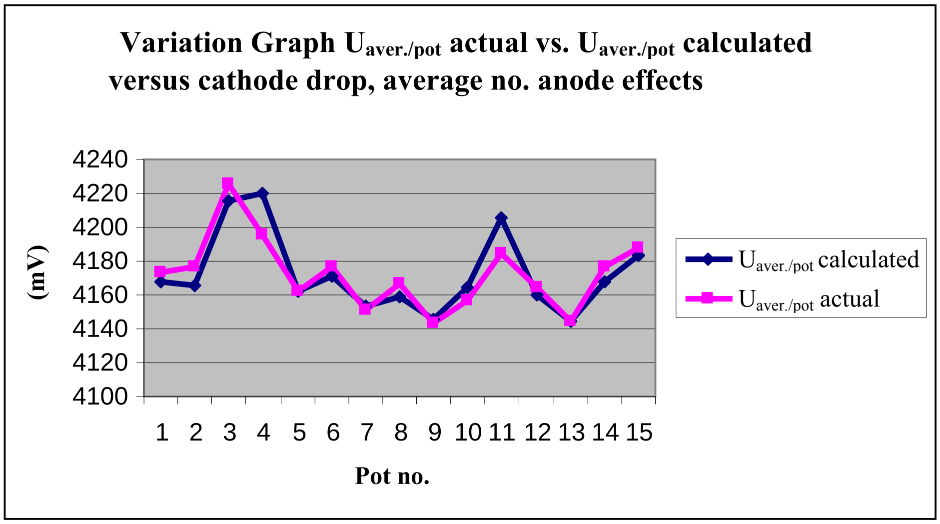

Fig. 3. Variation Graph $U_{aver./pot}$ actual vs. $U_{aver./pot}$ calculated versus cathode drop, average no. anode effects

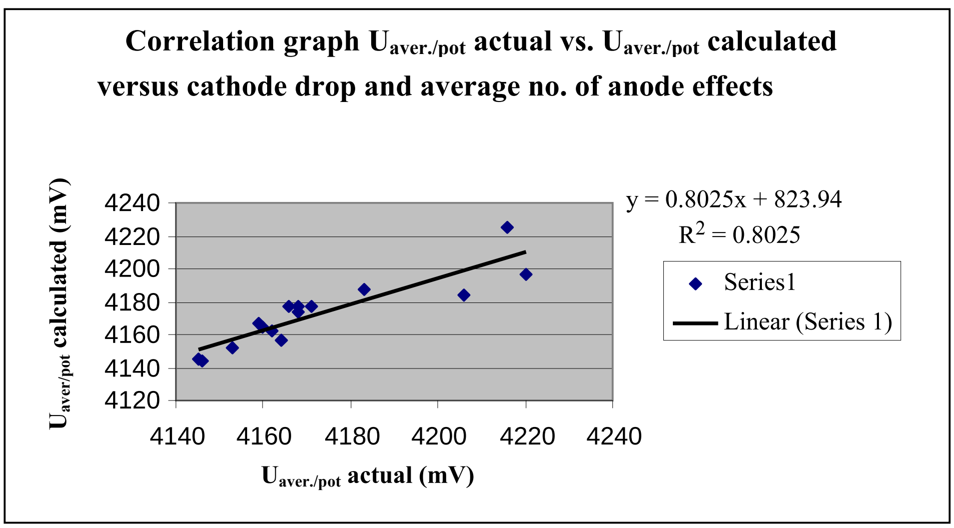

Fig. 4. Correlation graph $U_{aver./pot}$ actual vs. $U_{aver./pot}$ calculated versus cathode drop and average no. of anode effects

Further, the LINEST function is used to calculate $U_{aver/pot}$ calculated depending both on the cathode drop and on the rest of the parameters that can influence the pot $U_{aver.}$ and consequently a status of the pot thermal condition.

Fig. 5 and 6 present the evolution of actual $U_{aver/pot}$ and calculated $U_{aver/pot}$, depending on the cathode drop and on the average number of anode effects, the pot age and the actual instability average per pots.

The obtained equation has a higher degree of correlation as compared to the calculation equations (1) and (2) reaching a correlation level of 91.3%, against 70% - equation no. 1 and 80% - equation no. 2 respectively.

$$\mathbf{U_{aver./pot}\ calculated} = 3901.95 + 58.04*\text{Average AE} + 60.78*\text{Cathode drop} + 0.0013*\text{Pots age} + 197.73 * \text{elongation per pot} \quad (3)$$

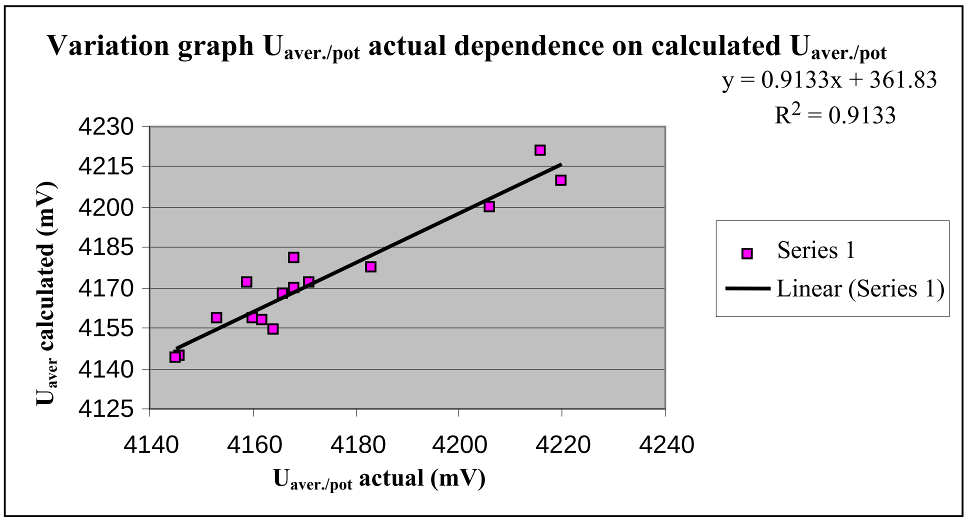

Fig. 5. Variation graph $U_{aver./pot}$ actual dependence on calculated $U_{aver./pot}$

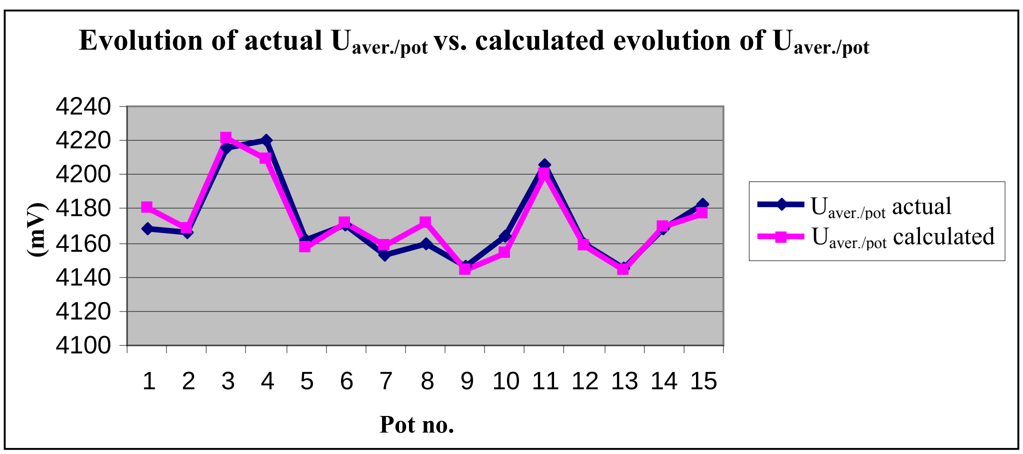

Fig. 6. Evolution of actual $U_{aver./pot}$ vs. calculated evolution of $U_{aver./pot}$

Table 1 presents two months' average values resulted for actual $U_{aver./pot}$ and for calculated $U_{aver./pot}$ by means of equation # (3).

Table 1

Average values resulted for actual $U_{aver./pot}$ / calculated $U_{aver./pot}$ by means of equation # (3)

Test section	$U_{aver./pot}$ actual [mV]	$U_{aver./pot}$ calculated [mV]	+/- [mV]
Pot 1	4168	4181	-13
Pot 2	4166	4168	-2
Pot 3	4216	4221	-5
Pot 4	4220	4209	11
Pot 5	4162	4158	4
Pot 6	4171	4172	-1
Pot 7	4153	4158	-5
Pot 8	4159	4172	-13
Pot 9	4146	4145	1
Pot 10	4164	4154	10
Pot 11	4206	4200	6
Pot 12	4160	4159	1
Pot 13	4145	4144	1
Pot 14	4168	4170	-2
Pot 15	4183	4178	5

Taking into consideration the good correlation of equation (3) as regards $U_{aver./pot}$ calculated, which has been determined on the 15 pots of the test section, the same formula is being applied for a group of pots in one of the smelter's potrooms to check as to what extent the said equation leads to a similar degree of correlation.

For this group of pots we have used the average values achieved on the pots during a two month period (the pots younger than 200 days were excluded).

The application of the same formula on this particular group of pots led to a degree of correlation similar to that obtained in the test section (Fig. no. 7 and 8)

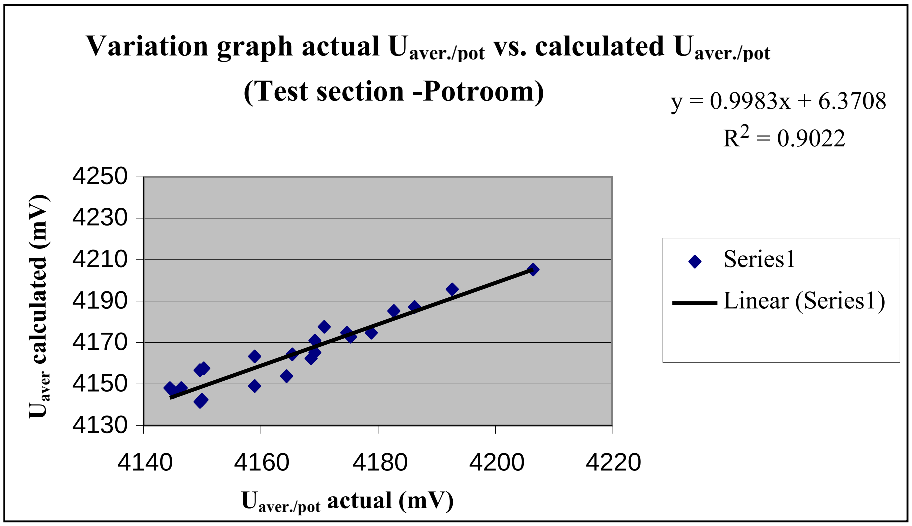

Fig.7 Variation graph actual $U_{aver./pot}$ vs. calculated $U_{aver./pot}$ (Test section - Potroom)

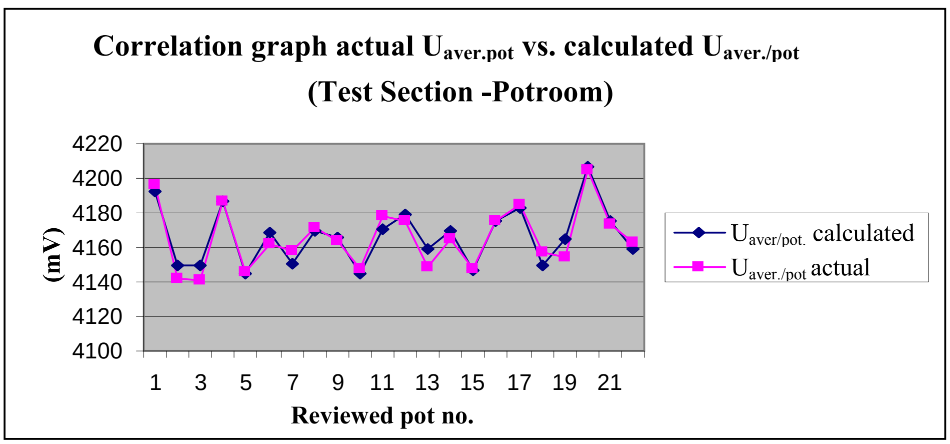

Fig. 8. Correlation graph actual $U_{aver./pot}$ vs. calculated $U_{aver./pot}$ (Test section - Potroom)

Table 2 shows the differences between the $U_{aver./pot}$ actual on the pots, during a two month period and $U_{aver./pot}$ calculated based on the calculation by means of equation (3).

The differences between the two average voltages are less than 10 mV, with a very good degree of correlation (more than 0.9).

Table 2

The differences between the $U_{aver./pot}$ actual on the pots, during a two month period and $U_{aver./pot}$ calculated based on the calculation by means of equation (3).

Pots in a potroom	$U_{aver./pot}$ calculated [mV]	$U_{aver./pot}$ actual [mV]	+/- [mV]
Pot 1	4193	4196	-3
Pot 2	4150	4142	8
Pot 3	4150	4141	9
Pot 4	4186	4187	-1
Pot 5	4145	4146	-1
Pot 6	4168	4162	6
Pot 7	4150	4158	-8
Pot 8	4169	4171	-2
Pot 9	4165	4164	1
Pot 10	4144	4148	-4
Pot 11	4171	4178	-7
Pot 12	4179	4175	4
Pot 13	4159	4149	10
Pot 14	4169	4165	4
Pot 15	4146	4148	-2
Pot 16	4175	4175	0
Pot 17	4183	4185	-2
Pot 18	4150	4157	-7
Pot 19	4164	4154	10
Pot 20	4206	4205	1
Pot 21	4175	4173	2
Pot 22	4159	4163	-4

4. Conclusions

The high degree of correlation between $U_{aver./pot}$ actual and $U_{aver./pot}$ calculated based on the average values of the main pot parameters prove that, in order to set a reference resistance for a pot, the value must be calculated and it should not be imposed by a process operator without a calculation basis.

The use of reference voltages in the operation of pots, under the optimum limit, does not necessarily bring about a lower actual average voltage, because periodically the pots can undergo instability conditions that will entail additional voltages, in order to bring them back to the normal operating limits, as well as additional technological work.

Moreover, it has been shown that high pot instability can influence not only the actual efficiencies but also the average number of anode effects due to the fact that the effectiveness of the automatic calculation method used to calculate the tendency during phase # 2 (prior to decrease of %Al_2O_3 below 1.8% and consequently the occurrence of anode effect) drops significantly.

Practically, imposing a reference resistance that would ensure as low as possible pot instability level can bring about both lower average voltage and upper Faraday efficiencies.

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