Proceedings of Iran International Aluminium Conference (IIAC2018)
April 24-25, 2018, Tehran, I.R. Iran

Optimization of energy consumption in primary aluminum production by Lowering the pot voltage (Case Study:Almahdi Aluminium Smelter)

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Abstract: The line of one of complexes of Al-Mahdi Aluminum Company has 240 production pots with a nominal current of 175 kA. In these pots, the electricity transmission is from the bus bars at both sides of the tap and the duct that lateral bus bars have less surface metal stability compared to those in the input pots. These pots have 18 anodes and 17 cathodes. These pots are fed by linear breakers in the tap and the duct sides, the feeding operation and the voltage regulation of these pots are performed by automation controlThe technical knowledge of working with pots in this complex has been experimentally obtained by performing production operation processes over the years. The decrease in the consumption voltage of production pots and the increase of ampere efficiency through various methods have always been on the agenda over the years and followed up.I have been supervisor in this workhouse for many years and in many cases, I have presented and implemented some programs to reach these objectives. Moreover, it should be noted that in 2003, I have directly cooperated with a Russian group to reduce the voltage of a number of pots.

One of the methods proposed to reduce the voltage of the production pots was to change the type of their feeding from linear feeding to intrusive feeding as follows:Regarding the fact that in each linear feeding, 3 or 4 dumps alumina were poured on the crust and 75-100 kg of urine was introduced into the pot, it was decided to work on the on pots with the lowest cost and feed the pots in a position similar to the point feeder by installing two punches on each breakers in the tap and the duct side and directing the aluminum inside in the Orebine towards these punches. The purpose of this decision was to reduce the voltage of the pots and increase the efficiency as well as prevent deposition of excess alumina on the cathode, This was accompanied by the problems discussed in this article.

Keywords : “voltage; aluminium smelter, electrolyze cell”

Introduction

Almahdi Aluminum was established in Bandar Abbass , the center of Hormozgan province , in July 1990 with an approximate investment of 1.5 bUSD , targeting 110,000 Mt aluminum per year increasable to 330,000 Mt/y. The first phase was inaugurated in 1997 and by early 2002 , it reached to half capacity using 120 cells in operation. The erection of 2nd phase of line one was started in 2002 and completed in May 2005. In June 2006 , the 2nd phase , called hereafter Hormozal , was started with an investment of 600 m euros.The technology of 2nd phase was D20 with the line current of 230 kA and 228 cells aiming annual production of 147,000 Mt aluminum. With cooperation of Iranian experts and foreign EPC contractor, FATA Hunter s.p.a from Italy , the whole project finished in 40 months and inaugurated in October 2009.For the time being 124 cells are in operation and the plan is to achieve full line capacity by mid 2015. ALMAHDI Aluminium Corporation (AAC), once considered a modern plant, is now concerned with the issue of old reduction cell technology which is far away from currently used technologies. The plant which is located near the city of Bandar Abbas, has a total number of 240 reduction cells which utilize center break and center feed systems. The amperage of the production line is 175kA that in comparison with recently installed plant is around the half

Fig1-Almahdi Aluminium Smelter

The above figure shows Al Mahdi Aluminum Company, which has been registered with the company site.

It is essential that the proper heat balance is maintained in a pot if maximum production and energy efficiency are to be achieved.

Heat balance is the relationship between heat input to the pot and heat losses from the pot. The heat input to a pot can be altered by changing the pots individual voltage or the line amperage. The heat losses from a pot can temporarily change due to routine operations such as anode changing, metal tapping, feeding and anode effects but the heat balance should not be allowed to significantly change, otherwise process efficiency will be lost. It is therefore important to maintain a pot at its correct voltage if its heat input is to remain steady.

POT VOLTAGE ITS COMPONENTS

The total voltage of a pot has to overcome 5 main resistance areas (see diagram).

- Any electrolytic reaction requires a given voltage to bring about the decomposition. This voltage is called the decomposition voltage (E).
- The voltage required to overcome the resistances in the anode assembly (Ra) i.e. from bus bar to bottom of anode.
- The voltage required to overcome the resistances in the cathode assembly (Rc).
- The voltage required to overcome the resistance in the bus bar (Rb).
- The voltage required to overcome the resistances in the anode cathode distance (Racd).

Note: E, Ra, Rc, Rb can be considered constant under normal conditions, Racd is a variable, and it is this resistance which is used in the calculation by the computer for ACD adjustments.

RELATIONSHIP BETWEEN VOLTAGE, RESISTANCE & AMPERAGE

The total pot voltage is given by the relationship:

$$Vt = E + IRt$$

and the total pot resistance by:

$$Rt = \frac{Vt \quad E}{I}$$

Where E = Zero amperage extrapolation (assumed constant at 1.65 V)

I = Current

Rt = Ra + Rc + Rb + Racd

as an example:

If Line current is 175 kA and the resistance setpoint of a pot is 12.4 micro ohms, then the pot will be controlled at a voltage of ;

$$V = E + IR$$

$$= 1.65 + 175,000 \times 12.40 \times 10\ 6 = 5.5 \text{ volts}$$

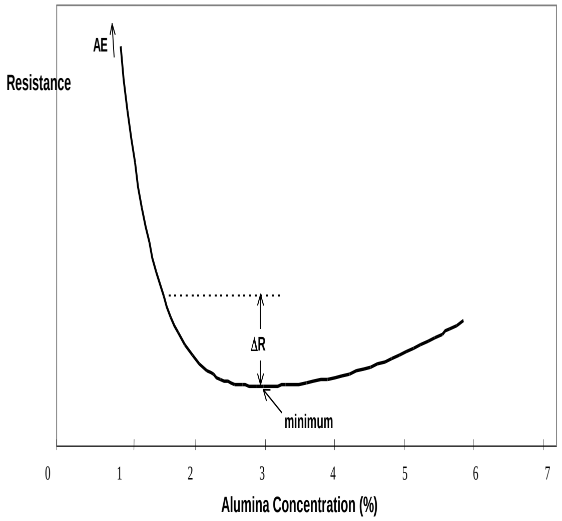

Figure 2-relation between alumina feed and pot resistance

Work method

Experimental Procedure (Model) Normally, the center line of hard crust is broken by cortex breaker jacks. In this method, there is no good control on the added alumina and while loosing much heat from central channel, also during each break

large amounts of hard solid crustentered into the molten bath and disturb the pot's stability. By chaning the feeding system to point feed, Almahdi company was able to increase the height of alumina covering on the anodes, reduce the metal height and changes bath chemistry, thus decreasing waste heat and in turn reduced the voltage of pot and specific energy consumption

Also with these changes, the occurrence of anode effects significantly reduced and alumina usage was controlled better which resulted in a significant decrease of sludge (Sludge)on the pot's cathode.

The demand feed cycle makes use of the relationship between alumina concentration and cell resistance as illustrated in Figure 3-2. During the underfeed, the monitoring of cell resistance to determine when a suitable end-point has been reached is referred to as a resistance search.

The authors should present the materials and experimental procedures briefly. Please identify the complete name and address of the companies which provided the materials and equipment.

Primary detection

Pots 26 and 27 usually operate at a high voltage of 4.93 and low voltage causes their instability.
These pots are unstable after depletion of the metal and it needs time to make them stable.
After the setting operation, the voltage must be set at higher value to prevent their instability.
As these pots were unstable after the tapping operation, the initial guess was that they had a small amount of metal storage, despite the fact that the measure of these pots was larger than the 27.5 cm before depletion.
After two setting operations in these pots, with the pulling measure from the central channel to the walls, it was found that firstly, the foot of the loge inside the pot was very grown and covered the cathode, and secondly, the thickness of the walls loge was high.
Since after each instability, the pot was stabilized through anodic correction, and the voltage was often set at high value and then it was decreased quickly, it was expected that there is no suitable anode adjust in these two pots and also the pot side loge was not formed at the proper temperatures, and possibly, after each anode effect and the relative warming of the pot, pieces of the side loge that were formed at a higher temperature on weak layers, were floated at the lower temperature inside the pot within the butt and caused instability. Pictures 2 and 3 are taken by the research team.

Figure 31- design rom in pot

Figure 4- Orbine Funnel(duct side)

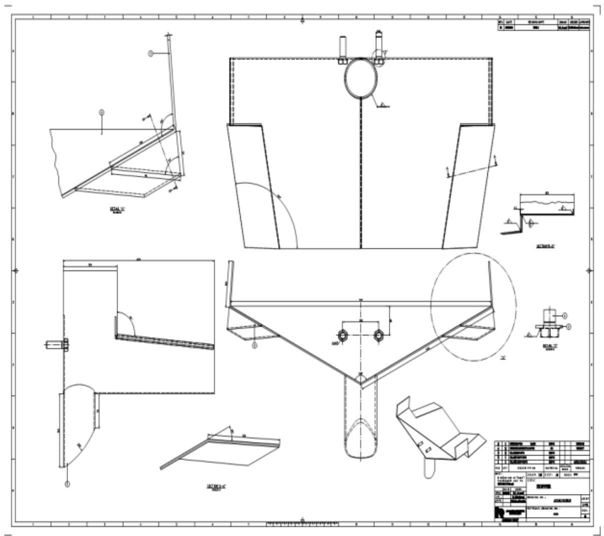

Figure 5- Orbine map for point feeding

Results and Discussion

Reducing the voltage

The line of one of complexes of Al-Mahdi Aluminum Company has 240 production pots with a nominal current of 175 kA. In these pots, the electricity transmission is from the bus bars at both sides of the tap and the duct that lateral bus bars have less surface metal stability compared to those in the input pots. These pots have 18 anodes and 17 cathodes. These pots are fed by linear breakers in the tap and the duct sides, the feeding operation and the voltage regulation of these pots are performed by automation control

The technical knowledge of working with pots in this complex has been experimentally obtained by performing production operation processes over the years. The decrease in the consumption voltage of production pots and the increase of ampere efficiency through various methods have always been on the agenda over the years and followed up.

I have been supervisor in this workhouse for many years and in many cases, I have presented and implemented some programs to reach these objectives. Moreover, it should be noted that in 2003, I have directly cooperated with a Russian group to reduce the voltage of a number of pots.

One of the methods proposed to reduce the voltage of the production pots was to change the type of their feeding from linear feeding to intrusive feeding as follows:

Regarding the fact that in each linear feeding, 3 or 4 dumps alumina were poured on the crust and 75-100 kg of urine was introduced into the pot, it was decided to work on the on pots with the lowest cost and feed the pots in a position similar to the point feeder by installing two punches on each breakers in the tap and the duct side and directing the aluminum inside in the Orebine towards these punches. The purpose of this decision was to reduce the voltage of the pots and increase the efficiency as well as prevent deposition of excess alumina on the cathode, but the following problems were created:

1 - At each feeding, alumina did not enter the pot as identical dumps, and varied from 0.7 to 5 kg

2 - According to the type of software, it was not possible to define the feeding time in seconds, and there was limitation to select the numbers to 2, 3, 4 or 5 minutes.

3 - Considering the fact that the punches was installed on linear breaker using jacks with a lot of courses and the alumina was conducted by metal plates through falling the linear orbines towards the punches, setting the time at least two minutes caused to take the equipment out of the schedule.

4. In some of these pots, there was no expected anode effect due to the inadequate feeding, and energy consumption was not reduced.

5. The voltage of these pots was not reduced significantly as expected.

6 - They were unstable after the anode effect or metal depletion or setting operation.

The following project was developed and implemented successfully for two pots with numbers of 26 and 27, which had worse situation comparing to similar pots in the above state.

Table 1- Weight drop feeders before correcting(pot27)

DATE	FEEDER 1(KG)	FEEDER 2(KG)	FEEDER 3(KG)	FEEDER 4(KG)	SUM	AVG
89/11/27	2.97	2.76	5.52	2.84	14.09	3.52
89/12/04	خراب	خراب	5.51	2.38	7.89	3.95
89/12/11	3.04	2.76	4.39	3.16	13.35	3.34
89/12/23	2.88	2.71	4.53	3.8	13.92	3.48
90/01/02	2.61	2.05	3.94	2.89	11.49	2.87
90/01/18	2.41	2.41	4.07	4.02	12.91	3.23
90/01/23	2.91	2.54	3.6	3.43	12.48	3.12
90/01/30	2.73	1.51	3.43	3.4	11.07	2.77
90/02/07	2.33	2.22	3.16	2.85	10.56	2.64
90/02/14	2.9	2.56	4.49	3.33	13.28	3.32
90/02/20	2.9	2.56	4.49	3.33	13.28	3.32
90/02/28	2.69	2.45	4.17	3.95	13.26	3.32
90/03/11	2.87	3.38	4.5	3.19	13.94	3.49
90/03/03	2.78	2.66	4.02	3.24	12.70	3.18
90/03/10	2.87	3.38	4.5	3.19	13.94	3.49
90/03/24	2.9	2.99	Empty	3.31	9.20	3.07
90/04/07	2.96	2.81	4.35	3.55	13.67	3.42
90/04/22	2.88	2.68	3.97	3.51	13.04	3.26
90/05/04	2.88	3.11	4.03	3.54	13.56	3.39

Table 2- Weight drop feeders after correcting(pot27)

DATE	TIME	FEEDER 1(KG)	FEEDER 2(KG)	FEEDER 3(KG)	FEEDER 4(KG)	SUM	AVG
90/05/13	10:00	3.4	2.61	4.46	3.78	14.25	3.56
90/05/13	12:00	3.45	2.82	4.47	3.53	14.27	3.57
90/05/13	14:00	3.98	2.615	4.27	3.61	14.48	3.62
90/05/13	17:00	3.51	2.685	4.28	3.64	14.12	3.53
90/05/13	19:00	3.32	2.62	4.315	3.435	13.69	3.42
90/05/13	21:00	3.74	2.86	4.51	3.785	14.90	3.72

Table 3-5-28 day process data pot 27

11:23:35 15/08/2011

28 Day Process Data. Pot A027. Tue 19/07 - Mon 15/08.

Date	Bath Tem dgrC	Metal Ht cm	Bath Ht cm	No. AE	Avg Volts V	Base Volts V	Noise V	Auto Dumps	Xs AlF3 %	AlF3 Addn kg	Man Dumps	Cathode Drop mV	Avg AEs Duration mins	Avg Temp Volt Adder V	Avg AEs Energy kWh	Avg AEs Voltage V	AlF3 Added kg	Tapped Metal kg
19/07	966	26.0	24.0	0	4.700	4.660	0.030	329	4.4	60	9	381		+0.035			60	0
20/07	966	26.0	20.0	0	4.669	4.650	0.023	346	5.8	60	14	381		+0.016			60	1710
21/07	960	26.0	26.0	0	4.625	4.650	0.023	317	5.8	60	0	381		+0.001			60	1730
22/07	957	26.0	26.0	1	4.674	4.650	0.027	314	5.8	60	2	381	2.2	+0.012	117	19	60	1750
23/07	957	27.0	26.0	0	4.650	4.650	0.024	329	3.3	30	0	381		+0.003			30	0
24/07	957	26.0	24.0	0	4.650	4.650	0.020	341	3.3	60	7	381		+0.003			60	1710
25/07	955	26.0	24.0	0	4.661	4.650	0.021	332	7.1	30	20	421		+0.012			30	1710
26/07	961	26.0	22.0	0	4.660	4.646	0.023	300	7.1	45	22	421		+0.003			45	1750
27/07	964	26.0	22.0	0	4.646	4.640	0.023	296	7.1	30	14	421		+0.005			30	0
28/07	964	26.0	24.0	0	4.646	4.640	0.019	342	7.1	30	0	421		+0.003			30	1750
29/07	963	26.0	21.0	0	4.651	4.640	0.020	353	7.1	30	0	421		+0.004			30	1750
30/07	962	27.0	22.0	2	4.672	4.640	0.022	378	7.1	30	19	421	1.1	+0.001	57	20	30	1750
31/07	962	27.0	22.0	0	4.674	4.640	0.020	298	7.1	30	8	421		+0.022			30	0
1/08	962	26.0	23.0	0	4.634	4.631	0.018	349	7.1	30	0	421		+0.005			30	1750
2/08	961	26.0	22.0	0	4.631	4.630	0.018	350	6.1	30	0	421		+0.004			30	1710
3/08	966	26.0	24.0	2	4.762	4.630	0.019	393	6.1	60	27	421	4.2	+0.018	243	20	60	1710
4/08	966	26.0	24.0	0	4.647	4.630	0.017	393	6.1	60	10	421		+0.003			60	0
5/08	964	27.0	22.0	2	4.685	4.624	0.018	427	6.1	60	23	421	1.8	+0.004	94	20	60	1750
6/08	954	27.0	23.0	0	4.635	4.620	0.017	398	7.3	30	5	421		+0.003			30	1900
7/08	957	27.0	26.0	0	4.630	4.620	0.017	393	7.3	30	2	410					30	1900
8/08	957	27.0	26.0	2	4.629	4.620	0.026	417	7.3	30	45	410	2.1	+0.046	91	18	30	0
9/08	957	26.0	24.0	0	4.682	4.620	0.018	384	7.3	30	30	410		+0.038			30	1750
10/08	957	26.0	24.0	0	4.605	4.620	0.028	369	7.3	30	1	410		+0.006			30	1750
11/08	957	26.0	22.0	0	4.632	4.620	0.019	399	7.3	30	0	410		+0.001			30	1750
12/08	957	26.0	22.0	0	4.649	4.620	0.028	384	7.3	30	7	410		+0.026			30	0
13/08	957	27.0	26.0	1	4.784	4.620	0.022	382	7.3	30	8	410	3.5	+0.075	191	19	30	1750
14/08	947	26.0	26.0	0	4.573	4.620	0.022	409	8.6	0	6	410		+0.003			0	1750
15/08	947	26.0	26.0	1	4.700	4.620	0.023	204	8.6	0	3	410	1.8		105	22	0	0
Month	Avg	Avg	Avg	Avg	Avg	Avg	Avg	Avg	Avg	Avg	Avg	Avg	Avg	Avg	Avg	Avg	Avg	Avg
	959.3	26.29	23.68	0.39	4.659	4.634	0.022	354.5	6.61	37.0	10.1	408.9	2.37	+0.014	128.2	19.9	37.0	1252.9

Table 4-5-28 day process data pot 27

14:01:52 3/09/2011

28 Day Process Data. Pot A027. Sun 7/08 - Sat 3/09.

Date	Bath Tem dgrC	Metal Ht cm	Bath Ht cm	No. AE	Avg Volts V	Base Volts V	Noise V	Auto Dumps	Xs AlF3 %	AlF3 Addn kg	Man Dumps	Cathode Drop mV	Avg AEs Duration mins	Avg Temp Volt Adder V	Avg AEs Energy kWh	Avg AEs Voltage V	AlF3 Added kg	Tapped Metal kg
7/08	957	27.0	26.0	0	4.630	4.620	0.017	393	7.3	30	2	410					30	1900
8/08	957	27.0	26.0	2	4.629	4.620	0.026	417	7.3	30	45	410	2.1	+0.046	91	18	30	0
9/08	957	26.0	24.0	0	4.682	4.620	0.018	384	7.3	30	30	410		+0.038			30	1750
10/08	957	26.0	24.0	0	4.605	4.620	0.028	369	7.3	30	1	410		+0.006			30	1750
11/08	957	26.0	22.0	0	4.632	4.620	0.019	399	7.3	30	0	410		+0.001			30	1750
12/08	957	26.0	22.0	0	4.649	4.620	0.028	384	7.3	30	7	410		+0.026			30	0
13/08	957	27.0	26.0	1	4.784	4.620	0.022	382	7.3	30	8	410	3.5	+0.075	191	19	30	1750
14/08	947	26.0	26.0	0	4.573	4.620	0.022	409	8.6	0	6	410		+0.003			0	1750
15/08	952	27.0	22.0	1	4.666	4.620	0.021	418	8.6	0	5	410	1.8	+0.001	105	22	0	1750
16/08	956	27.0	22.0	0	4.648	4.608	0.020	393	8.6	0	14	410		+0.019			0	1300
17/08	965	27.0	20.0	0	4.624	4.600	0.019	442	8.6	0	4	410		+0.005			0	1750
18/08	954	25.0	21.0	1	4.750	4.593	0.021	476	8.6	30	1	410	5.2	+0.034	376	25	30	1650
19/08	956	26.0	24.0	0	4.610	4.600	0.027	512	8.6	0	3	410		+0.006			0	1750
20/08	956	26.0	24.0	0	4.657	4.600	0.032	315	8.6	30	0	410		+0.031			30	0
21/08	956	26.0	26.0	0	4.875	4.600	0.040	395	8.6	45	18	396		+0.135			45	1950
22/08	971	26.0	26.0	0	4.745	4.600	0.053	262	7.3	30	4	396		+0.033			30	1750
23/08	971	26.0	23.0	0	4.655	4.600	0.034	368	7.3	30	10	396		+0.001			30	1850
24/08	971	26.0	23.0	0	4.739	4.600	0.025	370	7.3	30	12	396		+0.041			30	0
25/08	962	26.0	22.0	0	4.721	4.600	0.019	245	7.3	15	5	396		+0.075			15	1750
26/08	956	24.0	28.0	0	4.637	4.600	0.017	385	7.3	15	7	396		+0.003			15	700
27/08	954	24.0	28.0	0	4.601	4.595	0.019	414	7.3	0	0	396		+0.007			0	1200
28/08	960	24.0	22.0	0	4.601	4.579	0.018	402	7.3	30	14	396		+0.003			30	0
29/08	960	24.0	26.0	0	4.613	4.560	0.023	384	7.3	15	11	396		+0.043			15	1710
30/08	960	25.0	25.0	0	4.574	4.560	0.019	370	7.3	0	3	396		+0.006			0	1850
31/08	964	25.0	23.0	1	4.585	4.551	0.022	396	7.3	45	0	396	2.2	+0.008	130	22	45	1850
1/09	964	25.0	23.0	0	4.549	4.550	0.018	378	7.3	45	2	396					45	0
2/09	960	24.0	24.0	0	4.573	4.547	0.018	379	7.3	45	0	396		+0.011			45	1750
3/09	959	24.0	24.0	0	4.535	4.538	0.018	243	7.3	0	0	396					0	1800
Month	Avg	Avg	Avg	Avg	Avg	Avg	Avg	Avg	Avg	Avg	Avg	Avg	Avg	Avg	Avg	Avg	Avg	Avg
	959.0	25.64	24.00	0.21	4.648	4.595	0.024	381.6	7.67	22.0	7.6	403.0	2.95	+0.026	178.4	21.5	22.0	1321.8

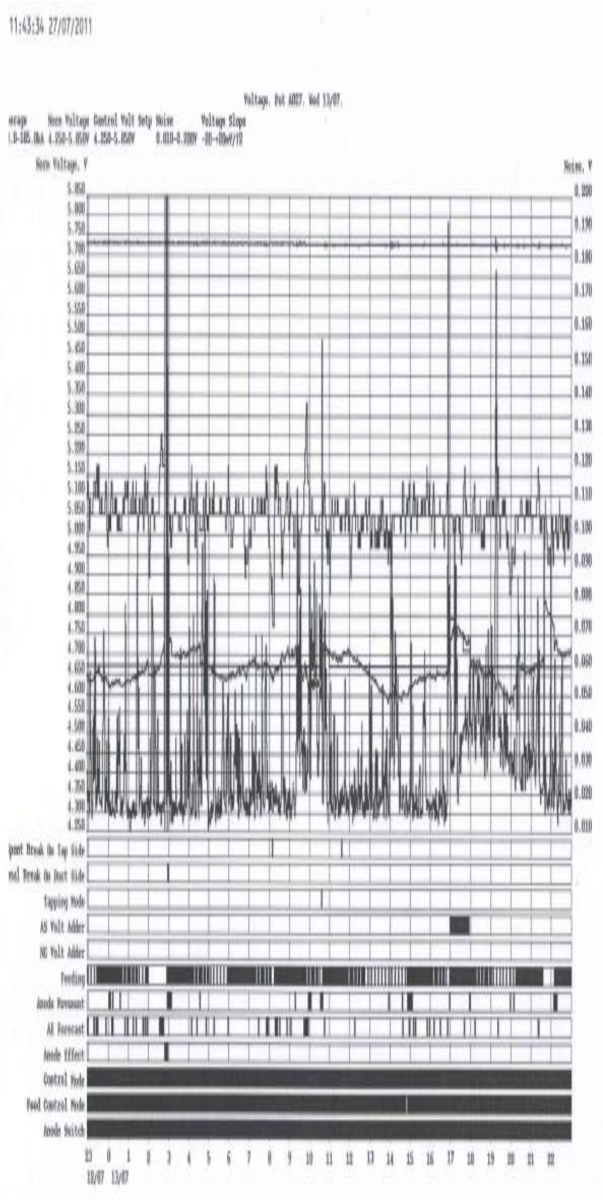

Figure 2- unstable pot

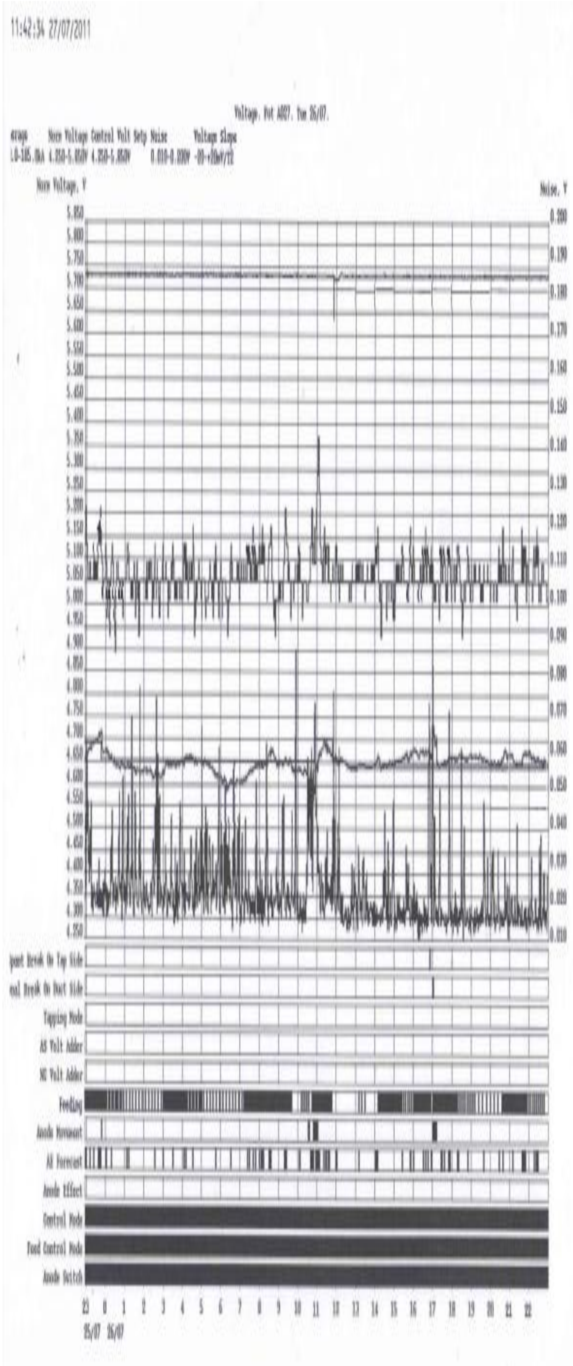

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Figure 8- pot stab and final voltage

1 - Correction of lateral loge and reduction of loge foot length:

First, the pot voltage was increased to 6.3 to melt all loges formed at different temperatures. Then, addition of all additives of the pot were completely stopped,

Description of Operation

the height of the metal surface was decreased rapidly with respect to the prediction of low metal storage of the pot and it reached to below 20. At the next stage, the voltage was slowly decreased like new pots to 5.3 volts, the pot was given an opportunity to form lateral loges without the presence of additional fluoride aluminum.

2- Anode Adjust

A full course setup was performed with monitoring the operation accuracy and anode setting without any subsequent manipulation to correct mV.

Despite the fact that the anode mV was very high or low, the high-mV anodes were allowed to not be manipulated as much as the anodes could tolerate to have the bottom of all anodes in one level.

3 – Correction of the clamps drop

Most of the times were spent on cleaning the junction of the rod with the ring bus. The junction loss was decreased by brushing to below 20 mV.

Preparing the millivolt of anodes and the losses of the joints clamp was on the agenda and was carried out regularly.

4. Correction of the loss of joints of collector bar and plugs

In several cases, the joints of cathode and pot plugs were measured and they were corrected.

5 - Take care of the appropriate size of the cover on the anodes

The thickness of the cover was fixed at about 5 cm due to the gradual reduction of the voltage, and the cover with appropriate meshing and proper amount of the mixture of alumina was used to prevent accumulation of heat or loss of it from the pot and do not impact on the formation or melting of the side loge

6 - Measurement of the oreing in the location of each punch

According to the following calculations, it was decided that the amount of each oreing of each punch would be about 2.85 kg

7 - Automation

The following calculations illustrate decision for time periods in different base feeding windows are very high feeding, high feeding, feeding in search mode, and starvation window to prevent undesired anode effect. Moreover, these calculations determine the weight of each feeder. This amount of feeding was an important factor in the sustainability and increasing the efficiency of pot that they will be discussed in the discussion and conclusion section.

Conclusion

In this work amperage decrease with o.41 volt per por:

(0.41/4.93)*100= 8.32 %

Less energy consumption

0.41*175*24*45 = 77578.56 toman Saving day

77578.56 * 365 = 28316174.4 toman Saving year

28 million and 300 thousand tomans per year will conserve electricity.

Increasing efficiency from 90% to an average of 93% :

8.053*175.2*0.9 = 1269.78 kg / Day

8.053*175.2*0.93 = 1312.13 kg/Day

1312.13 – 1269.78 = 42.35 kg Increase production per day

42.35*365 = 15457.75 kg Increase n production per year

Increased production has a higher power consumption and we have also saved savings due to reduced voltage.

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[5]Statistical information derived from operational research R&D Almahdi