INDUSTRIAL RUNNING OF THE 530KA POTLINE IN NORTH-WESTERN CHINA

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Keywords: Aluminum electrolysis, 530kA potline, Aluminum reduction cell, Busbar allocation, Cathode rod

Abstract

The 530kA potline has been put into industrial running in Xinjiang province, China. The potine includes 320 aluminum reduction cells and eighty cells are in production. It is the highest current potline in the world at present. A lot of new technologies were applied in the potline. Magnetic field was optimized, thus negative effect of vertical magnetic field was weakened and current distribution in cathodes was improved. Busbar allocation and installation was optimized, especially short-circuit busbar and upright-column busbar. High conductivity steel was used as cathode rods and three steel rods were installed in each cathode. Insulated layer was coated on each cathode steel rod near the cell sidewall. The potline has got low cell voltage and low anode effect frequency. Its cell voltage is about 3.90V and anode effect frequency is lower than 0.05 times per cell day. Further optimization and improvement need to be performed to get better performances.

Introduction

Nowadays, people pay more and more attention to energy consumption and environmental performance due to poor energy supply status and worsening environment. In the 12th Five-Year Plan of China, the government proposed a restrained goal to reduce the average GDP-specific energy consumption by 20% and to cut down its main pollutants by 10%. Furthermore the government began to limit specific energy consumption of energy intensive industries such as thermal power, steel, cement and aluminum industries from 2012. So, smelters have to shut down potlines located in power limited regions and move their capacity to western China with rich energy sources. Large capacity aluminum reduction cells have showed their advantages during this shift of aluminum capacity.

The first 530kA potline including 320 cells was designed by Central South University Institute Co. Ltd. Its capacity is 450 kt/a. The potline belongs to Xinjiang Qiya Aluminum & Power Co. Ltd located in Changji autonomous prefecture, Xinjing province. The potline includes super-high amperage aluminum reduction cells with six current risers and forty-eight anodes [1] (see Figure 1). The potline was started in August 2012.

Figure 1a. The 530kA potline (six risers)

Figure 1b. The 530kA potline (forty-eight anodes)

Advantages of Super-high Amperage Aluminum Reduction Cell

Aluminum reduction cells are the main equipments at smelters, which directly relate to technical & economic targets of potlines. The amperage of potlines has increased from 4kA in early Hall-Héroult cells to 530kA. Operation performances of potlines have become increasingly better, benefiting from improvements and innovations of the smelting process. Super-high amperage potlines will bring the following advantages: lower energy consumption, lower exhaust gas emission, lower investment per ton of aluminum, higher labor productivity, convenience for industrial intensive production and obtaining better technical & economic targets.

Higher Energy Efficiency

The overall energy efficiency of Hall-Héroult electrolytic process is less than 50%. The larger, high amperage cells offer a path to increase energy efficiency and to decrease reactive power loss, especially heat loss. Heat loss of aluminum electrolytic cell has a close relationship with cell amperage [2]. Heat loss per area of electrolytic cell decreases gradually with increasing of cell amperage (see table I) bringing higher energy efficiency.

Table I. Relationship between cell ampere and cell heat radiating area

Cell Ampere	Heat Radiating Area of Cell Inner Wall	Heat Radiating Area per Kilo Ampere
kA	m^2	m^2/kA
230	83.37	0.362
400	139.27	0.348
530	154.33	0.291

Table I shows that the 530kA electrolytic cell has a smaller specific heat radiating area than the 400kA electrolytic cell. Therefore, the higher amperage electrolytic cell will help to reduce heat loss and achieve higher energy efficiency. Furthermore, if higher amperage electrolytic cells are used, fewer potlines and fewer rectifiers are needed for the same capacity smelter. Thus energy loss from power supply rectifiers will be reduced.

Lower Exhaust Gas Emission

Higher amperage electrolytic cells also enable greater fume collection efficiency [3]. At the same time, exhaust flow per kilo ampere will be lowered (see table II).

Table II. Connection between cell ampere and exhaust gas emission

Cell Ampere	Exhaust Gas Emission Per Cell	Exhaust Gas Emission Per Kilo Ampere
kA	m3/h	m3/h.kA
230	9500	41.3
400	12000	30.0
530	14000	26.4

It can be seen in table II that the 530kA electrolytic cell has a lower specific exhaust gas flow than for the 400kA electrolytic cell. Using higher amperage electrolytic cells facilitates gas collection and fume scrubbing. In summary, using higher amperage electrolytic cells offers benefits for both direct energy saving and for reducing exhaust gas flows.

Lower Investment Per Ton Aluminum

Construction investment can also be reduced using higher amperage electrolytic cells to build a similar capacity smelter. Fewer aluminum reduction cells require less aluminum busbar, steel structure can be reduced, footprint area of potrooms can also be reduced, and investment on supplementary and employee service facilities can be reduced (see table III).

Table III. Correlation of cell ampere with specific investment

Cell Ampere	kA	180	300	530
Potlines/Cells		3/720	2/660	1/320
Capacity	kt/a	380	500	450
Specific Investment Ratio	%	100%	85~90%	75~85%

Table III shows that one 530kA potline with 320 cells can produce as much aluminum as two 300kA potlines with 660 cells. Furthermore, specific investment can be reduced by 10% using 530kA electrolytic cell comparing with 300kA electrolytic cell.

Higher Labor Productivity

The per capita productivity will also be improved with higher amperage electrolytic cells, thus labor productivity can be increased (see table IV).

Table IV. Cell amperage and aluminum output per capita

Cell Ampere	kA	180	300	530
Potlines/Cells		3/720	2/660	1/320
Aluminum Output Per Capita	t/a.person	350	550	600

Using higher amperage electrolytic cell is helpful for increasing labor productivity. Higher amperage potline is very appropriate for smelters located in sparsely inhabited areas such as western China.

Main Innovations at 530kA Electrolytic Cell

Busbar design is more difficult with increasing cell amperage. Electromagnetic field and flow fields for the 530kA electrolytic cell were simulated and the busbar was optimized using a non-symmetrical busbar design and installing a six risers system along the length of the cell. Interaction among electrolytic cells in adjacent potrooms, adjacent cells in the same potroom and the shielding function of cell shell were fully considered in the simulation. Flow velocity and fluctuation of liquid aluminum/bath and its interface deformation were analyzed. Stability of the magnetic fluid was improved. Furthermore, a new type of busbar design reduced horizontal current and improved cathode current distribution. Vertical magnetic field $|Bz|max$ was dropped from 28.33Gs to 15.13Gs. Current deviation in cathode was less than 2% (Measured results at the plant). The busbar had no overload during regular operation or short circuit. The new busbar design was easily installed and resulted in less metal/bath interface deformation, slower liquid metal flow velocity, and improved cell stability compared to the other 500kA cell design. Modification of busbar design is very helpful to keep the electrolytic cell stable at low cell voltage status.

Satisfactory Heat Balance Design

The cell lining was designed by using 3D electromagnetic field coupling calculation model optimized for low cell voltage operation. Good temperature distribution and heat balance at cell lining of super-high amperage electrolytic cell were achieved. Temperature deviation in sidewall lining was less than 3.5%. Superheat of sidewall was 10~15℃ (Measured results at the plant). Thus the cell lining can be operated without distortion and suitable thickness. Furthermore the cell sidewall can be protected, prolonging cell life.

Smaller Middle Gap Between Two Rows of Anodes

The middle gap between two rows of anodes was reduced in the 530kA electrolytic cell installation. The gap between two rows of anode is 150 millimeters compared with traditional gap of 180~200 millimeters. Advantages of the smaller gap include enlarging the cell cavity, reducing cell shell width, and reducing specific investment.

Three-support Structure at Two Ends of Electrolytic Cell

Two base supports were installed at each end of the traditional electrolytic cell. Because the end base support should support most of the weight of electrolytic cell, insulation bricks on the end base support could easily be crushed resulting in the supporting beam collapsing. These defects could influence the stability of cell shell cradle. When cell current capacity increases to more than 500kA, the load on the end base support increases. This can result in potential problems when using the traditional two-support structure. A three-point support structure was installed on the 530kA electrolytic cell (see Figure 2). Load on the end base supports was reduced and the pressure was balanced by also improving the end support structure. Thus potential problems due to traditional two-support structure were avoided.

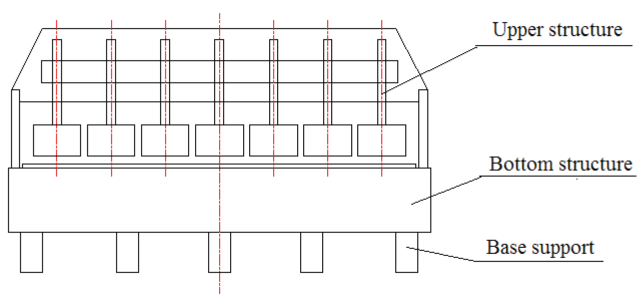


Figure 2a. Front view of electrolytic cell

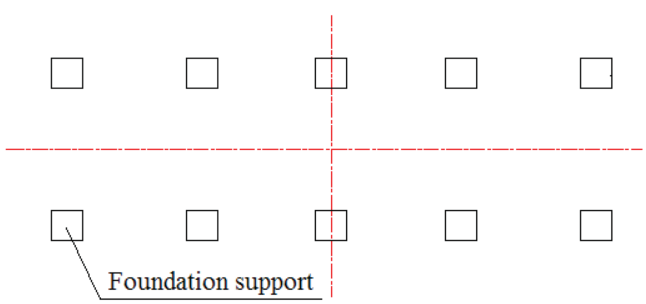


Figure 2b. Vertical view of traditional electrolytic cell foundation support

It can be seen from Figure 2 that there are two-point foundation supports at each end of traditional electrolytic cell and three-point foundation supports at each end of the 530kA electrolytic cell.

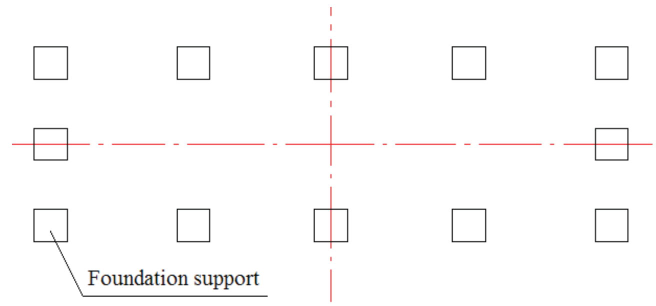


Figure 2c. Vertical view of the 530kA electrolytic cell foundation support

Improved Upper Structure of Electrolytic Cell

The upright column beam of the upper structure of the 530kA electrolytic cell was improved. The upright column beam is the main load bearing parts. A single-stem beam was installed on the 530kA electrolytic cell. Two upright column supports were installed at the beam ends and supported on the pot shell. The longitudinal center-to-center spacing is 19856 millimeters. The beam has the widest skip distance width compared to the other 500kA cells in China. The bottom margin of the beam still retains its horizontal stability after one-year of operation.

New Cathode Structure

Semi-graphite cathode blocks were used at the 530kA potline. The cathode cross sectional dimension is 450*740mm, and the cathode width is the same as that of anode block (anode size is 1800*740*600mm). Three cathode steel rods were installed in each cathode in order to get good cathode current distribution and reduce Fe-C voltages. Three smaller steel rods were installed at each end of cathode (see Figure 3). Thus the Fe-C contact area would be 0.7 times more than the former installation using the same total weight of steel. The improvement enlarged the Fe-C contact area between cathode block and cathode steel rod. This design will be helpful to decrease horizontal current and pot bottom voltage. The improvement of horizontal current in cathodes was evaluated by numerical simulation and about 15% of horizontal current caused by vertical magnetic field was cut down. Further evaluation will be done by measurement at the plan next year. Specific investment is reduced for consistent cathode height.

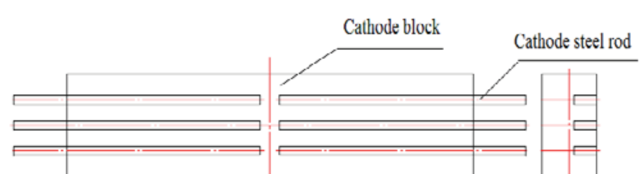


Figure 3a. Installation drawing of cathode block and its rods

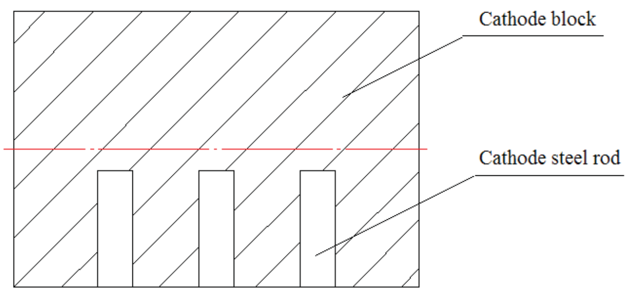


Figure 3b. Sectional view of cathode block and its rods

Industrial Operation of the 530kA Potline

The 530kA potline includes two potrooms with 160 cells in each potroom. Eighty cells of the 530kA potline were started-up in August 2012. Another eighty cells were put into running last month. In July, 2013, these cells will have been in operation for almost one year. Operation conditions of 530kA cells were optimized in 2013. Forty cells, from 1001# cell to 1040# cell, were surveyed. Cell voltage change curves of forty cells are shown in Figure 4.

The average cell voltage was about 3.90V. The running parameters for the cells in June 2013 are listed in Table V. Average current efficiency was 91.34% and average anode effect frequency was 0.038 per cell day. Running curves of two different cells are plotted in Figure 5. Line current was kept at 520kA.

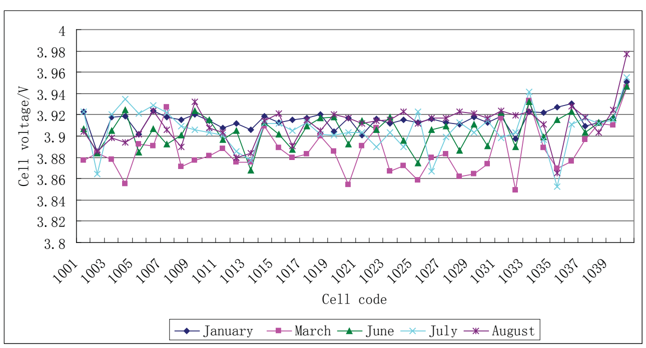
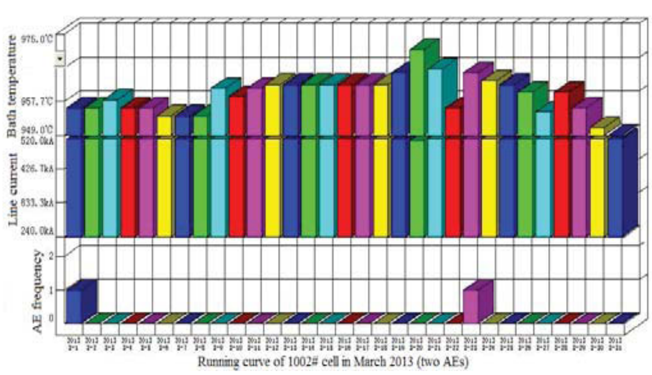


Figure 4. Cell voltage change curve of forty cells in 2013



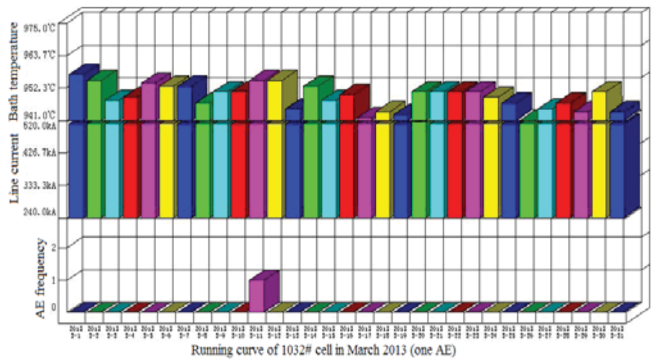


Figure 5. Running curve of two different cells in March 2013

Table V. Running parameters of forty cells in June 2013

Cell code	Cell voltage	Bath temperature	Current efficiency	Anode effect
	V	℃	%	count
1001	3.891	959	90.68	2
1002	3.897	954	90.79	2
1003	3.908	948	92.21	5
1004	3.908	951	92.92	2
1005	3.868	948	90.70	1
1006	3.898	947	91.66	1
1007	3.898	947	90.88	1
1008	3.888	945	91.53	2
1009	3.878	945	91.78	0
1010	3.888	948	91.52	0
1011	3.888	944	90.98	1
1012	3.898	945	90.85	2
1013	3.888	945	91.44	1
1014	3.928	943	90.72	2
1015	3.898	942	91.00	2
1016	3.888	946	90.97	0
1017	3.900	949	90.81	1
1018	3.888	945	90.78	0
1019	3.898	948	91.00	1
1020	3.898	944	93.58	0
1021	3.898	940	92.10	2
1022	3.898	945	90.85	1
1023	3.908	949	90.82	0
1024	3.888	946	90.76	0
1025	3.888	942	92.11	3
1026	3.888	954	90.77	2
1027	3.888	947	90.63	0
1028	3.868	947	90.86	2
1029	3.898	947	90.77	0
1030	3.888	950	90.66	1
1031	3.898	941	90.76	0
1032	3.888	948	92.37	0
1033	3.898	950	90.66	2
1034	3.878	950	91.99	1
1035	3.878	957	92.51	2
1036	3.943	947	90.85	0
1037	3.878	954	92.46	0
1038	3.888	955	90.86	1
1039	3.898	947	93.31	0
1040	4.148	953	90.83	3
Average	3.901	948	91.34	*46

* Total anode effects in June 2013

Conclusions

The 530kA potline has been put into operation in northwestern China. The potine includes 320 reduction cells, 160 cells of which are currently in production. Operational performance of the first eighty cells started in 2012 was investigated. Electromagnetic field and busbar designs were optimized. A smaller gap between two rows of anode blocks was utilized and three smaller cathode steel rods were installed in the 530kA electrolytic cell. The potline operates with a low cell voltage and low anode effect frequency. Average cell voltage is about 3.90V and average anode effect frequency is lower than 0.05 times per cell day.

Average current efficiency of the potline is currently slightly lower than our design target of 93%. Line current of the potline is currently 520kA somewhat lower than the design target current. Further optimization and improvement will lead to improved current efficiency and higher line current.

Acknowledgement

This work was supported by The National Science and Technology Support Program (No. 2012BAE08B04).

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