Light Metals 2011 *Edited by: Stephen J. Lindsay*
TMS (The Minerals, Metals & Materials Society), 2011

Light Metals 2011

ALUMINUM REDUCTION TECHNOLOGY

Cells Technology, Development and Sustainability

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HIGH AMPERAGE OPERATION OF AP18 POTS AT KARMØY

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Keywords: High-Amperage, AP18, Cell Operation, Karmøy

Abstract

The AP18 potline at Karmøy has increased the amperage to 230 kA. This has increased the productivity and reduced the specific production costs. The operation showed some lack of performance at high amperage for the old pots designed for lower amperage. The old pots had too high heat input, resulting in thin side ledge and higher Si content in the metal. To improve the heat balance the pot voltage had to be reduced for the older pots, and this resulted in reduced current efficiency (CE). The cathode life was reduced to ~2250 days due to the use of graphitized cathode blocks and the increased amperage. The new cathodes designed for 230 kA show good operational results. The young pots show 94-94.5% current efficiency and 13.0 kWh/kg Al in energy consumption. Due to less bath volume in the new pots it has been a challenge to reduce the anode effect frequency.

Introduction

Karmøy started aluminium production in 1967, and the first potlines used the Søderberg technology. To increase the production it was decided to use the AP18 Prebake cell technology, and the AP18 potline at Karmøy was started in 1982. Later expansions increased the number of pots to 288.

- Start-up in 1982 108 pots
- Expansion in 1987 114 pots
- Expansion in 1997 66 pots

During the first 10 to 12 years the amperage was 175 kA, and then the amperage was gradually increased. From 1999 a booster rectifier was used for five pots as part of the amperage increase program [1]. The experience from the booster pots and other potlines in Hydro [5,10] has then been used to increase the amperage up to 230 kA.

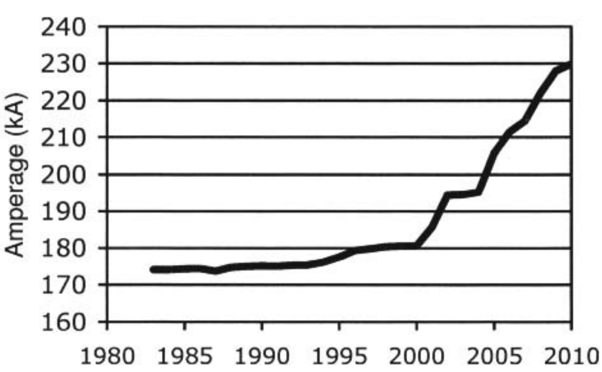

Figure 1. The amperage development at Karmøy.

The first amperage increase up to 200 kA was done with some modifications of the anode size and improved cathode block quality [1,2]:

- Longer and slightly wider anodes
- Deeper anode stub holes
- Graphitized cathode blocks

The amperage increase from 200 kA up to 230 kA will be further discussed here.

The amperage has been pushed up much the last years due to:

- High metal price (in periods)
- Power was available at an affordable price
- The cast house had extra capacity
- The rodding shop was able to rod more anodes
- Extra anodes were available from the suppliers
- The rectifiers had some surplus capacity
- Loss of production from the stopped Søderberg lines

The higher production also resulted in a higher productivity, as the number of employees was not increased with the increased production. This was an important contribution to reduced specific production costs.

However, some investments were necessary. Most investments were related to the use of the bigger anodes.

Main investments for increased amperage were:

- Booster rectifier – capacity 20 kA
- Extra transformers and rectifiers for higher amperage
- Change to bigger anode stubs, almost 40000 stubs
- Modifications in the rodding shop for bigger anodes
- Extra cast iron capacity for the bigger anode stub holes
- Modification of the potshells
- Transportation equipment for the bigger anodes
- New moulds for bigger anodes (by the anode supplier)
- Slot production in anodes (by the anode supplier)
- Forced suction in order to keep the emission limits

Combined investments the last ten years have been almost 30 million USD. The amperage increase from 200 kA to 230 kA has resulted in about 22 kt Al/y of increased production. This means average investments of about 1350 USD/t Al. Compared to new potlines (both Brownfield and Greenfield) this cost of extra production is low. For comparison the cost for the new potline in Sunndal (Brownfield expansion) was about 3100 USD/t Al [11]. Greenfield capacity requires much higher investments. For the expansion of the potline in Slovalco the expansion costs was about 1800 USD/t [6].

Anode improvements

The original AP18 anode size was increased to allow better utilization of the area inside the potshell. Later the use of thinner SiC slabs made it possible to increase the anode area further. Also the centre channel was reduced to maximize the length of the anodes. The anode length has been increased in steps up to 1630 mm so far. A smaller increase was done for the anode width. The anode width is limited by the small channels for chiseling between the anodes during anode change.

To reduce the voltage drop from the anode stubs to the carbon anode it was important to increase the contact area by increasing both the anode stub diameter and the anode stub hole depth. The bigger stubs also resulted in a higher heat loss through the stubs, which was important for the heat balance of the pot at higher amperage. All stubs (almost 40000) were replaced in a 6-weeks period. A similar change was also reported from Tomago as part of their upgrade to AP22 technology [8]. An alternative to the bigger stubs has been to increase the number of stubs to 8 stubs. The number of stubs has been increased in other plants in Hydro [4,6].

The big AP18 anode has a high surface area, and the use of slots has been important to reduce the bubble voltage drop. Introduction of slots reduced this voltage drop significantly (see figure 2). Different slot designs were also tested on the booster pots. In the beginning a single slot was tested. Later up to three slots were tested, but two slots in the anodes have been used for the regular pots. So far the slot depth has been increased up to 300 mm. Theoretically the slots should be even deeper, and deeper slots have a bigger potential to reduce the bubble overvoltage compared to a third slot. The slots are produced by the anode supplier, and the slot depth has been limited by the installed equipment for slot production.

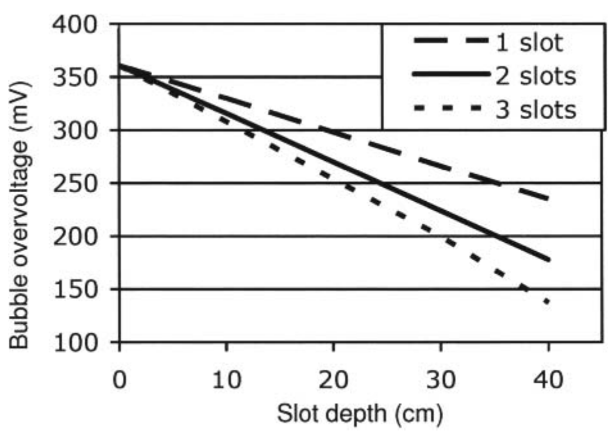

Figure 2. Calculated bubble voltage drops at 230 kA.

To maximize the anode cycle the anode height has been increased to 610 mm and the anode weight from 1180 kg to 1450 kg during the last 10 years (see figure 3).

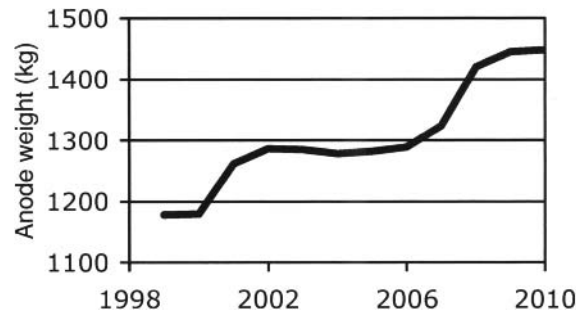

Figure 3. Anode weight development since 1999.

The last years the anode cycle has been stable at 80 shifts (26 and 2/3 days), and with the increased amperage this has resulted in a relatively thin anode butt and low gross anode consumption (510-520 kg/t Al). It has been important to have the 80 shifts anode cycle, as this fits with an anode changed every fifth shift (anode change every fortieth hour).

Cathode improvements

The original cathode used amorphous cathode blocks. During the years the graphite content in the cathode blocks was increased to graphitic qualities. These cathode blocks resulted in excellent cathode life (up to 3000 days). To reduce the cathode voltage drop and maximize the amperage graphitized cathode blocks were chosen. As a result of the higher cathode block erosion for graphitized cathode blocks the cathode life was also reduced.

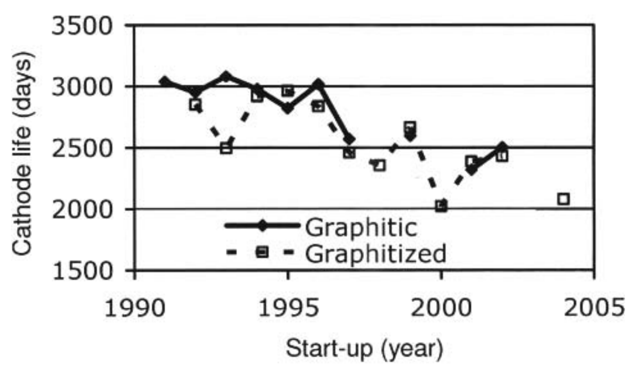

Figure 4. Cathode life development. Comparison between graphitic and graphitized cathode blocks.

Later the increased amperage has resulted in a further reduction in the cathode life to about 2250 days for the graphitized cathode blocks (see figure 5).

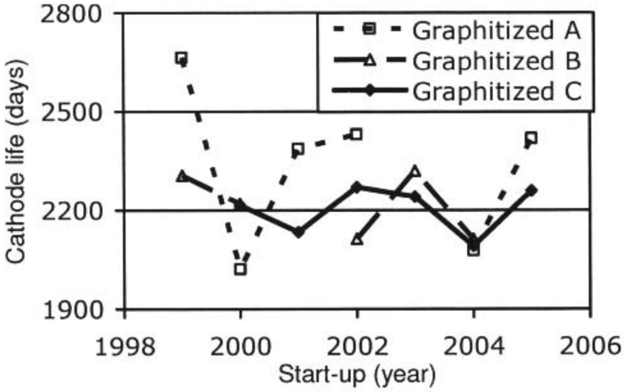

Figure 5. Development in cathode life for graphitized cathodes.

The cathodes were also modified to higher amperage by using:

- Higher and thinner SiC slabs
- Longer cathode blocks (to fit with the longer anodes)
- Bigger cathode collector bars (to minimize the cathode voltage drop)
- Reduced bottom insulation (to increase the heat loss)

The improved cathodes have resulted in a reduction in the cathode resistance.

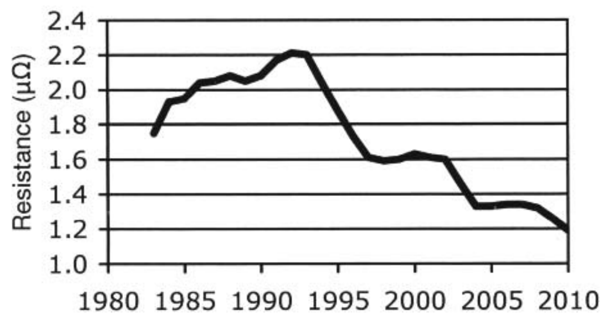

Figure 6. Development in average cathode resistance.

The 215 kA lining was, after verification in the booster section, introduced in the potline in 2002. Later the new 230 kA lining was verified in the booster section and used as standard cathode lining in the potroom from 2008.

Other improvements and tests

The forced gas suction was introduced in the potline in 2002-2003 to reduce the emissions from the pots [3].

Propane gas preheating was introduced in 2003. From then it was not necessary to have an anode effect at start-up [9].

The anode effect quenching was optimized in 2008 to reduce the duration. The average duration was then reduced from about 3 minutes down to about 1.5 minutes. This reduction has been important to minimize the emissions of greenhouse gases.

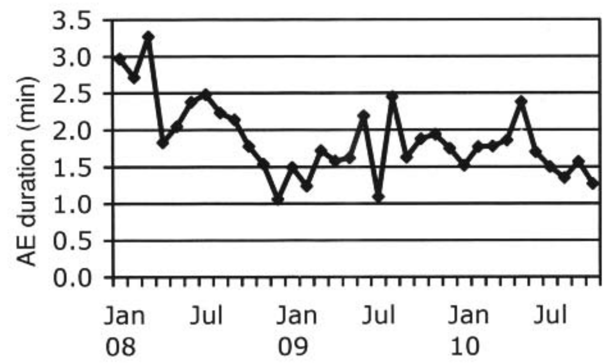

Figure 7. Development in average anode effect duration.

Magnetic field compensation has been tested in parts of the potline. So far the modifications in the busbar system have not resulted in increased performance, and it does not seem to be necessary for pot operation at 230 kA.

Laser-guided anode setting operation was introduced to reduce the fluoride exposure for the operators and improve the anode setting accuracy. This laser measurement method has also contributed to improved safety during anode change, as no operator is required to be close to the anode for accurate anode setting.

Operational Results

As the amperage increased, the side ledge was reduced in the oldest pots. For many of these old pots red shell sides were detected, and some pots also tapped out in the upper part of the potshell. These pots were not designed for the high amperage.

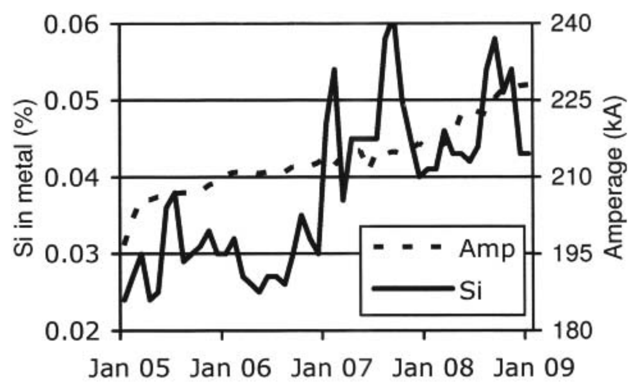

Figure 8. Si content in the metal increased with the amperage

As a result of the thin side ledge and the high Si content, a new 230 kA lining was introduced as standard lining in the potline from 2008. For the old pots the pot voltage and the bath acidity were reduced to get a thicker side ledge, reduced Si content and avoiding tap outs.

Also the CE was gradually reduced with the higher amperage.

This may be explained by different reasons:

- Higher metal velocity – results in a higher mass transfer number for the back reaction of aluminium
- Increased superheat
- Less side ledge and a larger metal area
- Low interpolar distance (ACD)
- Reduced bath acidity for old pots

Additionally it has been some anode problems, which also in periods contributed to a reduction in the CE. The average CE was reduced from about 94% in 2005-2006 to about 93%.

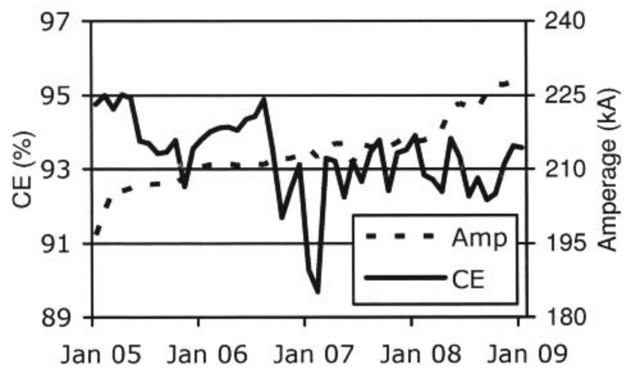

Figure 9. CE and amperage development in the potline.

The new 230 kA lining is a significantly colder lining than the old 215 kA lining. The Si content has been low, and the voltage has been higher. This higher voltage combined with reduced cathode voltage drop has resulted in a higher anode-cathode distance (ACD).

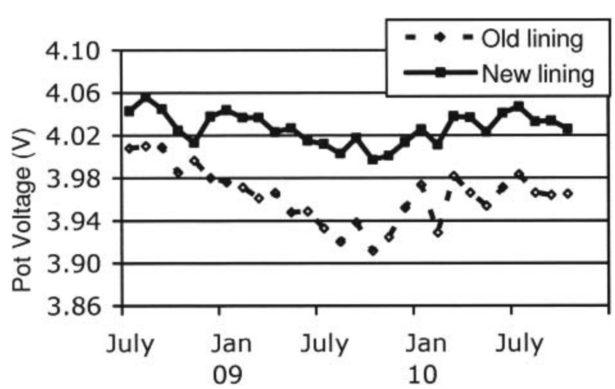

Figure 10. Pot voltage development for the old and new linings.

The introduction of the new 230 kA lining resulted in significantly better CE compared to the old lining designed for 215 kA (figure 11). The average difference has been more than 3%.

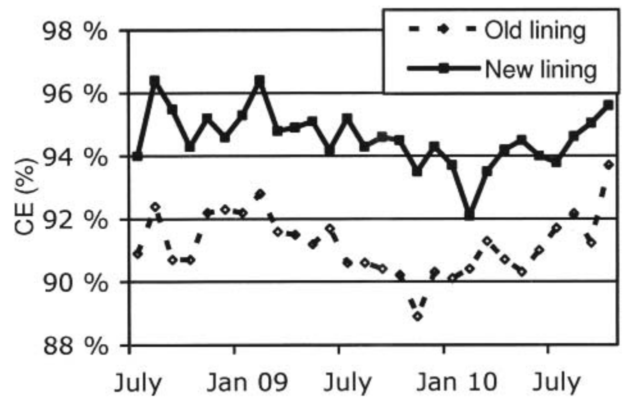

Figure 11. CE development for the old and new linings.

The improved CE has also contributed in lower energy consumption for the new lining, but also the old lining showed low energy consumption due to the low pot voltage.

Low energy consumption has always been given high priority at the Karmøy plant. The results for energy consumption in January-September 2010 (about 30 mV busbar losses from cross-overs, to and from rectifiers and between sections is not included):

- New 230 kA lining: 13.0 kWh/kg Al
- Old 215 kA lining: 13.2 kWh/kg Al

More modern technology:

AP39 [7] 13.15 kWh/kg Al

The energy consumption for the 230 kA cathode lining at Karmøy is better than reported by the AP22 technology in Tomago [8] and even better compared to the reported energy consumption for the more modern AP39 technology [7].

The bigger anodes have resulted in less molten bath in the pots. Less bath volume combined with the higher amperage results in more challenges to avoid AEs. This challenge increased for the new lining operating with a thicker side ledge – resulting in even less molten bath and more AEs compared to the old lining (figure 12). The pots with the new lining are more sensitive to low bath levels – figure 12 shows almost 0.2 AEs/day in February 2010, due to low bath levels. Another reason for the higher AE frequency for the new pots is that the metal level was also reduced for the new lining to increase the superheat. This resulted in reduced total liquid levels and reduced immersion of the breakers in the bath and more blocked feeder holes.

The AE frequency has later been improved during 2010, partly due to better bath control and slightly increased bath levels.

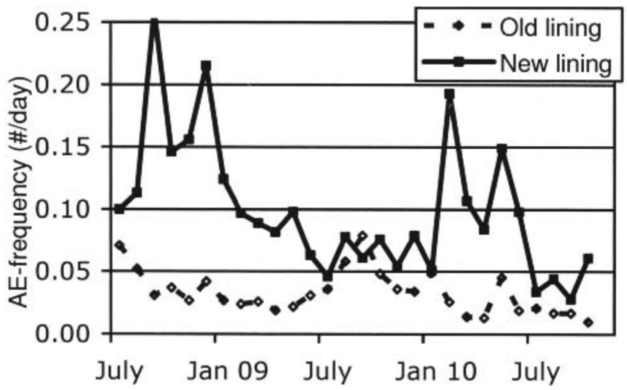

Figure 12. AE frequency development for the old and new linings.

Conclusions

The amperage at Karmøy has been increased to 230 kA. Extra metal production has been possible with small investments compared to new capacity.

The higher amperage has resulted in reduced CE for the potline, mainly due to reduced performance for the pot with the old pot lining. The old lining designed for 215 kA has shown lack of performance at 230 kA. The side ledge has been too thin in the old pots, and the high Si content in the produced metal comes from the SiC sidewalls. The thin side ledge has also resulted in more red shell sides and some tap outs for the old pots.

The booster pots have been used to develop and verify the new cathode for high-amperage operation.

The new 230 kA lining shows good results. The side ledge situation is good, and the pots can therefore be operated at a higher voltage and a higher ACD. The higher ACD also results in more stable operation and better CE. The energy consumption shows results comparable to or even better than more modern technology. The new cathode lining therefore also shows potentials for even higher amperage than 230 kA. The amperage may be increased to 240-250 kA.

The high amperage and the low bath volume have resulted in less stable bath level. This has resulted in a higher AE frequency for the new high amperage pots. The main challenge for the new pots has been to reduce the AE frequency at high amperage.

Acknowledgements

Hydro Aluminium Karmøy is acknowledged for the permission to publish the results for the high amperage operation.

References

1. O. Kobbeltvedt et al., "Experience from Amperage Increase on Test Pots in the Prebake Line at Hydro Aluminium Karmøy", Eleventh International Aluminium Symposium, Trondheim – Bergen – Trondheim, Norway, September 19-22, 2001, pp. 9-14.

2. J. Tonheim et al., "Experience with Booster Pots in the Prebake Line at Hydro Aluminium Karmøy", Light Metals 2004, pp. 191-196.

3. J. Tonheim et al., "Environmental Challenges in the Prebake Line at Hydro Aluminium Karmøy", Light Metals 2005, pp. 283-287.

4. B.P. Moxnes et al., "Potline Amperage Increase from 160 kA to 175 kA During One Month", Light Metals 2001, pp. 173-178.

5. B.P. Moxnes, H. Kvande and A. Solheim, "Experience and Pitfalls with Amperage Increase in Hydro Aluminium Potlines during the last 10 years", Light Metals 2007, pp. 263-268.

6. M. Bugge et al., "Expansion of the potline in Slovalco", Light Metals 2008, pp. 261-265

7. O. Martin et Al., "Development of the AP39: The New Flagship of AP Technology", Light Metals 2010, pp. 333-338.

8. L. Fiot et al., "Tomago Aluminium AP22 Project", Light Metals 2004, pp. 173-178.

9. O.A. Lorentsen and K. Rye, "Twelve years of experience with a fully automated gas preheating system for Søderberg and Prebake cells", Light Metals 2008, pp. 1001-1005.

10. O.J. Siljan et al., "Amperage Increase Experience in Hydro Aluminium", Ninth Australian Aluminium Smelting Technology Conference and Workshop, Terrigal, Australia, 4-9 Nov. 2007, pp. 319-333.

11. K.Ø. Vee, J.A. Haugan and A.H. Husøy, "Hydro Aluminium Sunndal Expansion Project", paper presented at the 2003 TMS Annual Meeting, San Diego, California, 2003.